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A study of the biology and control of the pea weevil, Bruchus pisorum L (Coleoptera, Bruchidae) in the Palouse area of Idaho and Washington

Tom A. Brindley
Iowa State College

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A STUDY OF THE BIOLOGY AND CONTROL OF THE PEA WEEVIL, BRUCHUS PISORUM L.

(COLEOPTERA, BRUCHIDAE) IN THE PALOUSE AREA OF IDAHO AND WASHINGTON

BY

Tom A. Brindley

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In Charge of Major Work

Signature was redacted for privacy.

Head of Major Department

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A STUDY OF THE BIOLOGY AND CONTROL OF THE PEA WEEVIL, BRUCHUS PISORUM L. (COLEOPTERA, BRUCHIDAE) IN THE PALOUSE AREA OF IDAHO AND WASHINGTON

INTRODUCTION

The growing of dried peas for seed and commercial purposes has become a very profitable source of agricultural income in the Palouse territory of Washington and Idaho. So profitable is this crop and so suited to the crop rotation system in vogue that the acreage grown has increased from practically nothing to 130,000[1] acres during the course of a few years.

The crop has at times, however, been seriously damaged by the pea weevil, Bruchus pisorum L. The insect, through its feeding, makes the pea seeds unfit for human consumption; reduces the germination to practically nothing, thus making the seeds useless for seed purposes; and makes them less valuable as stock feed. The following table shows the extent of the weevil damage as shown by the records compiled by the Washburn-Wilson Seed Company of Moscow, Idaho. The table presents the estimate made by men trained in this work for the information of this company (Wakeland, 1933).

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[1] Dealer's estimate for the 1934 acreage.

Table 1

Pea Acreage and Injury for the Period 1923 to 1934

Year	Acreage	Per cent injury
1923	30,000	6.0
1924	30,000	8.0
1925	25,000	12.0
1926	25,000	18.0
1927	40,000	20.0
1928	45,000	8.0
1929	60,000	5.0
1930	70,000	8.0
1931	65,000	10.0
1932	60,000	12.0
1933	100,000	4.2*
1934	130,000	

*Accurate figure taken from the Pea Grading Service of the University of Idaho coöperating with the Bureau of Agricultural Economics, United States Department of Agriculture.

It is evident from these figures that the pea weevil constitutes a serious menace to the profitable production of peas.

The individual farmer is held responsible for that portion of his crop that is weevil infested under the "dockage" system practiced by pea dealers. Under this system a farmer, unfortunate enough to have a badly infested crop, not only receives a lower price for his peas, but he is not paid for the portion that is found to be infested with weevils.

All of the weevil cost is not borne by the farmers, for the presence of the pest necessitates the use of expensive machines to remove the damaged seeds. Even the use of machines is not sufficient, for so exacting are the demands of the seed trade that all seed stocks are hand picked to insure the removal of all weevil-infested peas and off-type varieties.

Measures recommended for the control of the pest are entirely inadequate. The insect has increased in numbers and literally seemed to thrive under conditions which prevail when the fumigation of all seed stocks is practiced, a method of control which has been widely recommended to insure weevil-free peas.

The industry could not long withstand such losses nor continue its rapid growth in the face of the ravages of the insect. The Entomological Division of the Idaho Agricultural Experiment Station, quick to recognize the menace, began preliminary investigations on the ecology of the pest in 1926. The Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, began its investigations of the problem at the request of the Idaho Agricultural Experiment Station and a committee of interested bankers, business men and farmers of this territory. This thesis is, for the most part, a summary of a portion of the results of this investigation.

HISTORICAL

The indexes to the literature of Economic Entomology and to the Review of Applied Entomology list 247 references on the biological and economic aspects of the pea weevil. A few of these papers contain information of interest on the biology of the pea weevil and its control, but a large portion of them contains little of value to this study. Only those papers bearing directly upon this investigation will be reviewed. The literature has been very adequately listed by Wakeland (1933).

The original home of the pea weevil is unknown. At the present time it is known as a pest wherever peas are grown and the climate is favorable for its survival. Wakeland (1933) points out that climate is the chief limiting factor in the survival of the weevil and that it is known as a pest in all localities where peas are grown if environmental conditions are favorable for its survival.

The insect was named in 1767 (Linnaeus, 1767). It was known as a pest of peas in this country, however, as early as 1761. Peter Kalm (1761) reported that it was present in such numbers that the growing of seed peas was seriously curtailed in New York, Pennsylvania and New Jersey. It has since been introduced into almost all the pea growing localities in this country. The weevil probably gained access to the Palouse territory in seed peas carried by early settlers long before the seed pea industry began its development.

Harris (1841) states that the pea weevil was first noticed in Philadelphia from whence it spread to New Jersey, New York, Rhode Island, and Massachusetts. This author also stated that the insect probably spread from the United States to England and South Europe.

Trehune (1916) reported that the insect was introduced into British Columbia from the United States.

The original home of the pea weevil was probably not, however, the United States in spite of the fact that it was introduced into other localities from the United States, for the insect has no known host plant except the cultivated pea, _Pisum sativum_, which was unknown to this country before its introduction. Bridwell stated that he believed the insect had an Asiatic origin.*

The life history of the pea weevil has been mentioned in many publications throughout the world. Many of them are erroneous in view of our present knowledge, but on many points there is complete concurrence. Only those papers in which the life history has been treated in detail will be mentioned.

The pea weevil emerges from infested seeds in the fall and spring. Those that emerge in the fall pass the winter in storage places, in cracks and crevices out-of-doors, in rubbish, or possibly on the ground (Zavitz and Lochhead, 1903) (Larson and Hinman, 1931) (Wakeland, 1933). In certain localities in Russia the weevil is unable to hibernate successfully out-of-doors during the winter months (Korab, 1927). Weevils have also been known to fly several miles to hibernate (Korab, 1927) (Wakeland, 1933).

Skaife (1918) reported that pea weevils could survive well into a

*Statement by J. C. Bridwell during conference on the Bruchidae.

second winter in hibernation. Korab (1927) writes that the time the peas begin to bloom is the time when the weevils appear on the flowers, feed on the pollen of the pea flower, and lay their eggs on the green pods. This author also reports that the egg laying period can wholly be included in a period of 15 days and that the average number of eggs laid by each female is between 126 and 222.

The larva of the insect feeds and develops within the seed, but only one adult matures in each seed (Korab, 1927). Larson (1931) reports the emergence of weevils from shattered peas at harvest time.

Very few parasites of the weevil are reported in the literature. Skaife (1918) mentions Bruchocida orientalis Crawf. as a pest of the weevil. Bruchobius laeticollis Ashm. was listed by Pierce (1908) and by Cushman (1911) as having been reared from the pea weevil. Korab (1927) found the egg parasite Bruchoctonus senex Grese infesting as high as 60 per cent of the eggs of the insect. This author also reported a mite, Pediculoides ventricosus Newport, as a predator.

The methods suggested to control the pea weevil are varied and many in number, but the constant reports of damage done by the pest point to their inadequacy. Whitehead (1930) points out that the control measures recommended must be fundamentally wrong for the insect has never been properly controlled.

Harris (1841) recommended the storage of seed peas for one year in a tight container, dipping them in hot water, and late sowing as methods of control. Riley (1880), Gilbert and Popenoe (1919) and Gibson (1918) also recommended holding peas for two years in storage.

Seed fumigation, particularly with carbon bisulphide, has been suggested by practically every author that has made recommendations for weevil control. (Riley, 1880) (Zavitz and Lochhead, 1903) (Fletcher, 1903) (Vinall, 1916) (Orton and Chittenden, 1917) (Skaife, 1918) (Gibson, 1918) (Korab, 1927) (Back, 1930). So universally has this method been adopted that it has become almost axiomatic among entomologists. Needless to say, if efficiently carried out, it will kill all of the weevils in the fumigated peas, but,as has been indicated by Larson (1931), the problem arises from the weevils that escape before the peas are bagged for fumigation.

Other methods offered for killing weevils in the peas or removing them from the peas are heat treatment (Kartzov, 1914), removing weevily peas by floating them off in water and then destroying the infested seeds (Pushkarev, 1919), dipping peas in boiling water (Skaife, 1918), dipping peas in kerosene (Pasca, 1880), dipping the peas in a solution of lime water or salt water (Kartzov, 1914), and killing the weevils by exposing them to the rays of the sun (Skaife, 1918). The majority of these suggestions are less efficient than fumigation and they likewise fail because no consideration is taken of the weevils that escape from the peas before the treatment is applied.

Trap plantings have been suggested (Kartzov, 1914), but no experimental data to show the results have been presented. Korab (1923) suggested seeding peas at such a time that the peas would start fruiting when the weevil would have finished its egg laying.

Korab (1927) also attempted to find pea varieties which were weevil resistant and to develop by plant breeding a pea which would be weevil resistant. So far, these efforts have been fruitless.

Riley (1880), Zavitz (1903) and Fletcher (1903) advocate withholding all pea seedings for a period of one year.

Larson (1931) achieved satisfactory results by burning pea stubble after the peas had been harvested by combining. This method is limited to localities in which sufficient vegetation is produced to yield a cover that will carry a fire.

EXPERIMENTAL

Life History and Habits

Methods

All of the data presented herein were obtained as nearly as possible from insects living under conditions as they occur in the field. In cases where it was necessary to cage the weevils, they were observed under fluctuating conditions of temperature and humidity.

The study was made on the Alaska or First and Best peas, the two most common varieties of field peas grown in the area. Only first grade seed was used so the growth of the peas for experimental purposes would be typical and uniform. The choice of vines, the arrangement of plots, and the selection of the experimental insects were decided by chance.

Records for the oviposition habits of the insect were obtained from eggs laid on the pods of staked pea vines. The vines were tied to four-foot laths as often as they needed support. Vines staked in this fashion were held somewhat above the general level of the surrounding peas, but this was necessary to keep the vines from breaking through handling and to permit their ready identification.

Results of life history studies

The adult. Blatchley has described the adult as follows:

"Oblong-oval, subdepressed. Black, feebly shining; above, densely clothed with reddish-brown and whitish hairs; thorax with a triangular whitish space in front of the scutellum; elytra with yellowish, grayish and whitish hairs, the latter forming an oblique band behind the middle; pygidium covered with gray hairs except two oval black spots near apex; antennae black, the three basal joints rufous; legs black, front tibiae and tarsi rufous; under surface black, shining, densely punctate, sparsely clothed with fine grayish hairs. Thorax broader than long, coarsely and densely punctate. Elytra slightly longer than broad, striate, the striae finely punctate. Length 4.5-5 mm."

Much variation in the size of the insects occurs, the measurements for this locality showed the average length to be 5.5 mm. and the width at the thorax to be 2.00 mm. The width of the thorax in the smallest individuals measured only 1.09 mm. whereas the largest measured 2.27 mm. Females were found to be slightly larger than the males. Plate 2 shows the variation in the size of the insects. The size of the weevil is in some way regulated by the available food supply, for small, completely formed individuals emerged from small peas.

Records on the life history were obtained from pods on which egg deposition records were taken. A number of eggs, marked with waterproof ink on the pods, were allowed to remain and hatch; all other eggs laid on the marked pods were rubbed off. The insects that hatched from the marked pods were allowed to develop within the peas in the field until the seeds had ripened and the larvae were approaching the pupal stage. The peas were then taken into a field insectary and placed in wire-bottomed trays, as shown in Plate 1. The peas in these trays were examined daily until the adult stage was reached.

The pupal stage was determined by watching the individual pea seeds until the emergence window appeared. Two days following this event the window was opened with a sharp scalpel. By this time the larva was usually in the pre-pupal stage and the further development of the insect could be readily followed. This procedure apparently affected the development of the larva but little.

Life history data were also obtained by splitting weevil infested peas until the stage of the development of 250 individuals had been recorded. Plate 3 depicts graphically the difference in the size of peas in which weevils can develop.

As suggested by J. C. Bridwell, the sexes can be distinguished by the presence or absence of a small acute spine on the distal end of the tibia of the middle leg. This spine is present in the male and absent in the female.[2]

The insects are very active and alert. The slightest disturbance will cause them to feign death or take flight. The casual observer, for this reason, never sees the pea weevil adult.

Hibernation of the adults. The pea weevil spends the winter in hibernation in the Palouse region of Washington and Idaho either in stored peas or out of doors in a wide variety of situations. All the adults that can escape from the peas in the fall before harvest or from those peas lost on the ground during the harvesting process seek situations suitable for hibernation. The bark of trees, especially pine, cracks in fence posts and old buildings, the trash about the pea fields such as pine duff, debris beneath wild rose bushes, and old timbers and stumps, all have been utilized. The following table shows results obtained in the examination of

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[2] J. C. Bridwell. U. S. National Museum, Washington, D. C.

such debris around a badly infested field. The examination was made in April after winter mortality had occurred and before the spring flight had started.

Table 2

Localities in which Pea Weevils Have Been Found Overwintering (Moscow, Idaho; April, 1932).

Locality	No. Found	No. Dead	Per cent living
Two square feet of pine duff beneath a group of small pines	23	8	65.1
Same as above beneath a lone tree. One square foot	19	5	73.6
Same as above	26	12	53.8
One square foot of surface beneath a large lone rose bush near same field	14	1	92.8
Beneath a two by four, three feet long, lying in debris at the base of brush	14	6	57.1
An old rotten stump, beneath bark	24	16	33.3

The fence posts about this field were very heavily infested. A crack in one post held 502 hibernating individuals. The average for 175 posts examined about this field was 39. It took only 15 minutes to find 100 hibernating weevils beneath the bark of a ponderosa pine (*Pinus ponderosa*) near this same field.

Not far distant from this field in a large grove of ponderosa pine, 181 weevils were collected from a cage covering four square feet of bark on a large tree. Ponderosa pines seem to furnish an ideal hibernating place for the weevils, for very little mortality occurs among the insects hibernating in its bark.

One of the most interesting places in which the pest hibernated was under the trash and debris left on the pea field after harvest. Eight weevils were collected in a cage covering 12 square feet of the field's surface. These figures are extremely interesting, for the weevils were collected in the spring after they had been exposed to all the rigors of winter. As the cage was set at random, a like number probably could have been collected on the same area at many other points in the field. Such a survival on the harvested fields might account, of itself, for the large populations that appear each year in certain sections of this territory.

Adult insects have been found to be capable of passing two winters and one crop season in hibernation, of emerging at the beginning of the second crop season, and of laying fertile eggs.

Table 3

Survival of the Pea Weevil (*Bruchus pisorum* L.) in Threshed Peas, Moscow, Idaho.

Date	Weevils in peas		Weevils emerged		Total dead	Per cent dead
	Number	Number dead	Number	Number dead		
April 28, 1931	100	0	0	0	0	0
Nov. 4	66	0	48	0	0	0
11	78	0	32	0	0	0
18	52	0	49	1	1	1
27	72	0	35	0	0	0
Dec. 4	77	1	27	1	2	2
11	71	0	35	3	3	2
18	73	0	34	2	2	2
25	58	0	51	1	1	1
Jan. 1, 1932	82	1	21	0	1	1
8	94	2	18	2	4	4
15	79	2	31	0	2	2
22	84	0	16	0	0	0
29	88	4	15	0	4	3

Table 3 (Cont.)

Date	Weevils in peas: Number	Weevils in peas: Number dead	Weevils emerged: Number	Weevils emerged: Number dead	Total dead	Per cent dead
Feb. 6, 1932	86	1	19	0	1	1
13	52	1	51	1	2	2
20	58	6	38	0	6	6
27	56	0	55	0	0	0
Mar. 4	54	1	53	2	3	3
11	76	3	25	0	3	3
18	80	5	18	0	5	5
25	58	1	40	0	1	1
Apr. 1	73	0	28	0	0	0
8	50	0	49	0	0	0
15	52	0	45	0	0	0
22	22	0	78	0	0	0
29	81	2	16	0	2	2
No examination						
No examination						
May 20	70	0	19	0	0	0
27	22	0	70	0	0	0
June 3	45	0	55	0	0	0
10	20	1	64	1	2	2
No examination						
June 24	25	0	65	6	6	7
July 1	27	1	73	28	29	29
8	26	0	72	27	27	27
15	26	1	72	43	43	43
22	16	1	82	63	64	65
29	24	1	70	65	66	68
Aug. 5	44	2	56	46	48	48
12	31	3	65	62	65	68
19	24	6	72	67	73	76
26	34	13	65	56	69	70
Sept. 2	25	7	77	72	79	77
9	51	22	47	46	68	69
16	32	18	66	60	78	80
23	39	14	59	55	69	70
30	50	22	57	56	78	73

Table 3 (Cont.)

Date		Weevils in peas		Weevils emerged		Total	Per cent
		Number	Number dead	Number	Number dead	dead	dead
Oct.	7, 1932	38	15	59	56	71	73
	14	47	36	59	53	89	84
	21	33	14	65	63	77	78
	28	49	26	49	43	69	70
Nov.	5	48	22	55	51	73	70
	11	49	27	56	50	77	77
	21	35	24	65	65	89	89
	26	40	27	57	55	82	86
Dec.	2	46	35	53	51	86	87
	9	28	18	72	70	88	88
	17	49	32	50	46	78	79
	23	66	45	46	45	90	80
	30	47	38	48	48	86	91
Jan.	6, 1933	51	35	43	42	77	81
	13	55	40	45	45	85	85
	21	34	25	63	59	84	86
	28	40	29	59	56	85	86
Feb.	4	40	30	60	60	90	90
	11	32	21	64	62	83	86
	18	47	34	49	47	81	84
	25	42	32	61	60	92	89
Mar.	6	39	32	60	56	88	89
	11	54	36	55	55	91	83
	18	43	38	53	51	89	93
	25	47	33	50	48	81	84
Apr.	1	42	31	59	56	87	86
	8	42	32	56	53	85	87
	15	40	27	57	55	82	85
	22	34	28	67	62	90	89
	28	34	25	63	56	81	84
May	5	46	36	66	64	100	88
	14	28	22	67	57	79	83
	19	41	32	50	50	82	90
	27	38	31	70	65	96	89

Table 3 (Cont.)

Date	Weevils in peas Number	Number dead	Weevils emerged Number	Number dead	Total dead	Per cent dead
June 3, 1933	31	18	59	55	73	81
10	34	28	77	76	104	94
26	33	31	66	66	97	99
July 7	40	38	68	67	105	98
31	47	47	53	53	100	100

Table 4

Survival of the Pea Weevil (Bruchus pisorum L.), Remaining in Pea Pods at Moscow, Idaho.

Date	Weevils in peas Number	Number dead	Weevils emerged Number	Number dead	Total dead	Per cent dead
July 15, 1932*	66	2	34	0	2	2
22	57	4	43	3	7	7
29	61	7	39	9	16	16
Aug. 5	62	2	38	9	11	11
12	57	6	43	25	31	31
19	60	12	40	26	38	38
26	64	8	36	22	30	30
Sept. 2	49	15	51	41	56	56
9	58	24	42	33	57	57
16	67	24	33	26	50	50
23	64	30	36	28	58	58
30	58	31	42	35	66	66
Oct. 7	55	25	45	38	63	63
17	55	30	45	40	70	70
21	63	42	37	28	70	70
28	52	32	48	34	66	66
Nov. 5	55	31	45	44	75	75
11	55	43	45	39	82	82
21	55	39	45	42	81	81
26	57	40	43	41	81	81

Table 4 (Cont.)

Date	Weevils in peas Number	Weevils in peas Number dead	Weevils emerged Number	Weevils emerged Number dead	Total dead	Per cent dead
Dec. 2, 1932	59	38	41	40	78	78
9	59	45	41	39	84	84
17	63	50	37	34	84	84
23	86	60	59	55	115	80
30	85	60	68	67	127	83
Jan. 6, 1933	56	40	44	44	84	84
13	73	59	27	26	85	85
21	63	50	37	36	86	86
28	66	42	34	32	74	74
Feb. 4	66	55	34	32	87	87
10	79	70	21	21	91	91
17	63	52	37	33	85	85
24	63	56	37	37	93	93
Mar. 7	77	68	23	23	91	91
11	64	54	36	33	87	87
18	66	58	34	33	91	91
26	71	60	29	27	87	87
Apr. 1	61	53	39	37	90	90
8	63	54	37	33	87	87
15	64	54	36	35	89	89
22	63	51	37	37	88	88
28	68	64	32	30	94	94
May 5	55	46	45	42	88	88
14	61	55	39	37	92	92
19	57	53	43	42	95	95
27	56	50	44	43	93	93
June 3	58	52	42	40	92	92
10	59	54	41	39	93	93

*Experiment started during October, 1931, but first observations made on this date.

A grain sack of uncracked pods and a like sack filled with enough small sample bags containing 100 weevily peas were placed in storage where they would be subjected to fluctuating temperatures typical of warehouse conditions. The pea samples were prepared and stored at the end of October, 1931, and the study was completed in July, 1933, when the last living weevils were found. Tables 3 and 4 present the results of this study. It is apparent from these results that 7 per cent of the weevils in the uncracked pods and 11 per cent of the weevils in threshed peas were still alive at the start of the second crop season after they went into hibernation. These adults were placed on pea blooms on June 6, 1933, and eggs were obtained on June 23, which hatched on July 1. This is the first available record which shows that it is possible for the weevil to survive two winters in hibernation under actual storage conditions and to emerge to lay fertile eggs. This experiment indicates definitely the impracticability of advocating the extermination of the pea weevil by withholding all pea plantings for one crop season.

The weevils emerge from hibernation in large numbers during the first warm days when the air temperature exceeds 70° F. The emergence coincides usually with the blooming period of the volunteer peas. Seven weevils, in one case, were collected in 100 sweeps of a fifteen-inch collecting net on volunteer peas which were in bloom on June 5, 1932. Five days later, 1,015 weevils were collected in a like number of sweeps from the same patch. Weather conditions were quite similar on both days. A few weevils are able to find the pea crop before blooming starts, but these seem to locate the peas only by chance, for the weevils could be found on a large number of plants quite as abundant as they could be found on peas. When blooming starts, however, the weevils swarm on the peas in large numbers. The numbers collected in one field increased from an average of two weevils in 100 sweeps, when the peas were just starting to bloom, to an average of 839 in 100 sweeps in 11 days, when the peas were in full bloom. They almost competely ignore peas which are not in bloom for those which are; in one case, 1,415 weevils were collected in 100 sweeps of a fifteen-inch collecting net on a border planting which was in bloom, whereas only eight were collected in a like number of sweeps on younger peas immediately adjacent to the border. The weevils are apparently attracted to the peas by the odor of the blooms rather than by the color, for white blossoms attract the weevils in as large numbers as the colored blossoms. Plate 4 shows a pea weevil in a typical position on a pea blossom.

Feeding habits of the adults. The adults feed on the pollen of blossoming peas; if the infestation is severe they may feed on the calyxes or injure the developing pod by eating small holes in its surface. Plate 5 shows the typical feeding position of adults on the calyxes; Plate 6 shows the injury that results when weevils feed on the pods, whereas Plate 7 shows typical injury to calyxes. In the majority of cases, however, the weevils merely make their way into the interior of the flower to feed on the pollen; frequently two or more weevils may enter the same blossom. Adults that cannot find pea pollen will feed on that of other available flowers. They have been observed to feed on the pollen of yarrow, dog fennel, wild rose, and many other flowers.

Pollen of some kind is necessary before the pea weevil can lay eggs, but pea pollen is unnecessary. Seventy-five weevils taken from uncracked pods were placed on each of the flowers listed in Table 5 and allowed to feed. When mating was observed, the pods, from which all traces of the stamens had been removed, were added for egg deposition. Eggs were obtained from weevils which fed on dog fennel, goldenrod, yarrow, mustard, and on perennial sweet pea, but they were produced in much larger numbers by individuals that had been fed on pea pollen.

Oviposition. After feeding on the pollen of the pea for several days, the weevils mate and soon begin to lay eggs. Experiments were conducted at intervals during the summer of 1933 to determine how long it was necessary for the insects to feed on pea blossoms before they would mate and lay eggs. Twenty-five to 50 pea weevils, taken directly from peas to guard against previous feeding, were placed on a bouquet of blooms in a quart Mason fruit jar. Pods were placed in the jars and the cages were examined daily to determine when the first eggs were laid. Table 5 presents the results of this study.

Table 5

Number of Days from the Time Weevils First Feed on Pea Pollen Until the First Eggs are Laid. Moscow, Idaho, 1933.

Lot No.	Put on Blooms	First Egg Laid	Time
1*	June 6	June 20	14 days
2*	" 9	" 21	12 "
3*	" 9	" 19	10 "
4	" 12	" 19	7 "
5	" 13	" 18	5 "
6	" 27	July 3	6 "
7	" 28	" 4	6 "
8	" 29	" 4	5 "
9	" 30	" 7	7 "
10	July 6	" 10	4 "
11	" 8	" 14	6 "
12	" 8	" 14	6 "
13	" 17	" 24	7 "
14	" 22	" 26	4 "
15	" 27	Aug. 2	6 "
16	Aug. 11	" 19	8 "

*Weevils from 1931 crop.

The maximum time after weevils start to feed until the first eggs are laid was 14 days early in June and only four days at the latter part of August.

Much variation exists in the published literature on the number of eggs laid by the pea weevil. Skaife (1918) reported a maximum of 31 and an average of 24, but commented on the fact that the figures seemed very low. Korab (1927) found them to lay as high as 222 eggs with an average of 126 and stated "that the egg-laying period was not long and can be wholly included in a period of 16 days." Table 6 gives in detail the results of a study conducted to determine the number of eggs laid by the weevil in this climate and Table 7 illustrates the results of a similar study made during 1933.

These results were obtained by daily observations on caged fertilized females. The individuals were taken directly from pea seeds and placed in Mason fruit jars on pea blossoms. Here they were allowed to feed and mate until the first eggs were laid on pea pods placed in the jars. Female weevils were then placed in individual test tubes previously provided with a pea blossom and a pea pod. Each day the eggs were counted and a fresh pod and a fresh bloom were added. The cages were kept at room temperature in a field insectary.

Table 6

Daily Egg Deposition Records of the Pea Weevil (*Bruchus pisorum* L.) 1932

Dates of egg deposition	Pair Number 1	2	3	5	7	8	9	10	11	12	13	15	Daily Total	Max. Temp.	Min. Temp.
July 19	9	24	11	20									64	78	40
20	15	7	7	15	0	8	0	0	0	0	8	0	60	86	42
21	35	25	4	36	1	11	28	8	2	7	37	1	193	97	52
22	30	35	21	22	10	44	41	49	15	36	31	3	337	97	52
23	6	14	12	29	3	34	14	28	12	8	17	5	182	91	54
24	16	20	1	26	11	24	34	40	17	16	19	2	226	92	51
25	20	25	1	33	19	19	22	20	7	14	28	7	215	84	54
26	8	16	22	13	5	9	28	26	13	19	21	3	183	90	43
27	12	24	11	30	17	31	34	33	19	26	46	9	292	99	45
28	14	19	21	33	15	21	31	27	21	22	24	12	260	88	54
29	10	11	21	20	2	5	16	12	7	24	14	2	144	80	45
30	7	4	11	3	4	4	10	12	7	6	3	0	71	77	46
31	11	15	31	9	8	14	29	20	19	19	15	0	190	80	49
Aug. 1	21	10	14	18	9	8	22	18	10	13	14	4	161	81	61
2	29	18	24	23	14	24	23	35	31	27	56	15	319	91	45
3	12	14	4	20	12	23	23	4	11	19	5	2	149	95	47
4	20	26	6	25	24	40	10	21	21	18	28	12	252	95	45
5	21	19	16	21	15	21	10	28	23	7	23	2	206	95	50
6	14	14	0	25	8	46	9	19	15	6	21	1	178	94	46
7	11	14	0	26	2	24	7	17	5	*	32	2	140	100	50
8	15	23	0	21	12	24	12	15	8		11	0	141	94	56
9	13	8	*	23	20	36	5	14	7		14	0	140	76	49
10	2	5		4	8	7	2	2	9		*	1	40	74	48
11	0	1		3	3	0	0	1	2			0	9	70	53
12	4	2		0	0	7	7	4	3			2	25	78	52
13	30	5		5	9	15	2	6	8			1	71	84	40
14	7	12		18	13	10	0	*	0			1	61	68	44
15	19	12		10	9	7	2		0			2	61	97	48
16	16	31		10	7	12	15		1			1	102	97	54
17	22	8		8	4	9	6		4			1	62	96	51
18	14	3		5	6	3	6		3			0	40	94	46
19	0	9		6	1	5	4		4			0	29	85	45
20	12	4		4	0	0	0		2			0	22	82	46
21	0	6		3	0	2	0		2			0	13	86	45
22	10	8		9	0	1	0		5			1	34	78	53
23	2	4		2	4	0	0		0			0	14	79	38
24	10	8		8	9	2	4		5			0	46	66	40
25	25	11		8	9	2	0		4			0	59	88	46
26	7	15		7	4	3	3		7			0	46	87	43
27	*	3		3	7	3	5		0			0	21	89	45
28		6		0	2	6	0		1			0	15	72	46

Table 6 (Cont.)

Dates of egg deposition	Pair Number												Daily Total	Max. Temp.	Min. Temp.
	1	2	3	6	7	8	9	10	11	12	13	15			
Aug. 29		0		6	0	0	0		0			0	6	60	42
30		0		0	0	0	0		0			0	0	65	36
31		0		0	0	4	0		3			0	7	69	33
Sept. 1		3		0	0	0	0		0			0	3	68	45
2		0		0	0	0	0		0			0	0	71	31
3		6		6	2	0	0		0			0	14	80	29
4		6		0	1	2	0		1			0	10	82	34
5		4		9	7	4	0		0			0	24	91	40
6		3		2	1	1	0		0			0	7	83	49
7		13		17	2	0	0		1			0	33	88	41
8		14		4	0	1	0		0			0	19	68	50
9		5		0	0	0	0		0			0	5	74	30
10		1		0	1	6	1		0			0	9	86	36
11		1		3	0	0	0		0			0	4	70	39
12		0		0	0	0	0		1			0	1	76	34
13		4		2	0	0	0		2			0	8	79	33
14		3		0	0	0	0		0			0	3	80	40
15		4		0	1	0	0		0			0	5	85	33
16		2		7	0	2	0		0			0	11	85	33
17		2		5	0	3	*		0			0	10	69	35
18		0		8	0	0			0			0	8	55	34
19		0		2	0	0			0			0	2	50	37
20		0		3	0	0			0			0	3	63	46
21		2		8	0	2			0			0	12	67	30
22		0		3	0	4			1			0	8	75	30
23		0		0	0	1			0			0	1	78	27
24		2		3	0	1			0			0	6	68	33
25		2		0	0	0			0			0	2	70	38
26		11		3	0	1			0			0	15	72	29
27		2		1	0	2			0			0	5	79	32
28		9		3	0	0			0			0	12	82	39
29		0		3	0	0			0			0	3	82	38
30		6		3	0	2			0			0	11	80	34
Oct. 1		0		4	0	1			0			0	5	81	35
2		0		6	0	0			0			0	6	78	40
3		5		4	0	1			0			0	10	74	37
4		3		1	0	3			0			0	7	76	45
5		1		1	0	0			0			0	2	80	38
6		0		0	0	1			0			0	1	67	42
7		0		4	0	*			0			0	4	57	30

Table 6 (Cont.)

Dates of egg deposition	Pair Number 1	2	3	5	7	8	9	10	11	12	13	15	Daily Total	Max. Temp.	Min. Temp.
Oct. 8		0		0	0				0			0	0	55	36
9		0		1	0				0			0	1	55	23
Total No. of Eggs Laid	527	652	238	735	321	606	465	459	339	287	467	92			
Deposition Period, Days	39	79	18	83	57	79	52	24	64	17	21	33			

*Dead.
Pairs 4, 6, and 14 escaped shortly after the records were started.

Table 7

Summary of Egg Laying Records on the Pea Weevil (<u>Bruchus pisorum</u> L.) During 1933 at Moscow, Idaho.

Pair no.	Date put on blooms	Date first egg was laid	Total no. eggs laid	Total egg laying period in days	Condition at end of exp.	
1	June 13	June 18	265	47	Died	Aug. 4
2	12	19	344	46	"	4
3	12	19	22		Released	July 15
4	13	20	196		Escaped	15
5	12	21	133	26	Died	17
6	12	21	16		Released	15
7	12	21	18		"	15
8	12	21	240	52	Died	Aug. 15
9	13	21	276	34	"	July 25
10	13	21	192	25	"	16
11	12	20	262	42	"	Aug. 6
12*	6	23	172	23	"	July 15
13*	6	22	38	24	"	28
14*	6	22	235	90	Living	
15*	6	24	467	41	Died	Aug. 4
16*	6	25	110	33	"	21
17	18	29	331	34	"	4
18	18	July 1	276	23	"	July 24
19	18	2	63	19	"	21
20*	9	1	83	45	"	Aug. 30
21*	9	3	57	16	"	12

Table 7 (Cont.)

Pair no.	Date put on blooms	Date first egg was laid	Total no. eggs laid	Total egg laying period in days	Condition at end of exp.	
22*	June 9	July 1	235	23	Died	July 24
23	18	1	326	27	"	28
24	18	June 29	93	17	"	15
25	18	29	300	25	"	23
26	18	July 1	78	26	"	Aug. 13
27	**	2	131	42	"	21
28	**	3	172	32	"	3
29	**	3	56	17	"	July 24
30	27	4	158	16	"	21
31	28	6	133	16	"	22
32	28	4	64	30	"	Aug. 12
33	29	5	285	54	Living	
34	29	4	84	13	Died	July 21
35	29	5	224	35	"	Aug. 12
36	July 6	11	138	15	Escaped	July 25
37	6	11	98	19	Died	29
38	6	11	98	25	Living	
39	6	11	128	16	Died	Aug. 17
40	6	11	166	55	"	Sep. 18

* Weevils from 1931 crop.
**Taken while copulating in the field.

The results obtained by the author are in direct contrast to the figures obtained by other workers. A maximum of 735 was recorded with a minimum of 92 and an average of 432 from 12 individuals studied during 1932. The maximum oviposition period was 83 days, the minimum 17 days and the average was 47 days.

Field study of oviposition. The duration of the egg laying period in the field is of prime importance to the control of the weevil, for it is during this period that the actual damage to the pea crop begins. This study was designed to determine how long weevils under field conditions would continue to lay eggs if a continuous supply of vines were available.

how long an individual planting of peas would be susceptible to weevil damage, and, finally, how long an individual pod would be acceptable to the weevils for egg laying. The information presented here was obtained by planting peas at weekly intervals throughout the spring and early summer and then examining daily all the pods on 25 vines selected at random from each planting. Each day all the eggs on each of the pods or vines under observation were recorded. This study was carried on during 1932, 1933, and 1934.

The crop season of 1933 was especially favorable for pea growth so plantings were started on April 6 and continued for 11 consecutive weeks. Growth of peas was impossible after this date. Table 8 and Plate 8 present a summary of the number of eggs laid on 25 vines of each planting and show the ability of the weevils to continue laying eggs over a long period of time in the field. Eggs were laid from June 12 to July 21. A study of Table 34 shows that the eggs were fertile throughout this period. Table 9 gives a summary of the results of a similar experiment carried on during 1932 on three varieties of peas. Three varieties in three different localities were used for the tests. Oviposition, on each of the varieties, continued approximately the same length of time -- the maximum period was 25 days and the minimum 23 days. The peak of oviposition, in each of the groups studied, was reached about two weeks after the first egg was laid and then, after that time, although the temperatures remained high, the daily rate of oviposition dropped rapidly. Very few eggs are laid when the temperature falls below 70° F., and no newly deposited eggs could be found when the temperature fell below 65° F. Table 10 gives the detailed results of this experiment.

Table 8

Summary of the Number of Eggs Laid on 25 Selected Vines from Plantings Made at Weekly Intervals. Moscow, Idaho, 1933.

Planting Number	Date Planted	First Egg Laid	Total Pods on 25 Vines	Total Eggs Laid on 25 Vines
1	April 6, 1933	June 12	132	171
2	13	15	127	88
3	20	15	154	364
4	27	17	137	195
5	May 4	21	145	268
6	11	25	123	685
7	18	27	100	662
8	25	July 5	151	591
9	June 1	9	120	300
10	8	15	171	90
11	15	21	70	38

Table 9

Egg Deposition Studies on Three Varieties of Peas

Variety	First and Best (Volunteers)	Alaska (Volunteers)	Early Washington
Number of vines	150	50	25
Total number of pods	538	101	115
Total eggs laid on the vines	10,493	2,346	5,158
Average number of pods per vine	3.4	2.0	4.6
Average number of eggs per vine	69.9	46.9	206
Average number of eggs per pod	19.3	23.2	44.8
Date first egg was laid	June 9, 1932	June 7, 1932	July 6,1932
Date last egg was laid	July 2, 1932	July 2, 1932	July30,1932
Total time vines were suitable for oviposition	23 days	25 days	24 days

Table 10

Complete Egg Deposition Records on Three Varieties of Peas. Moscow, Idaho, 1932.

Variety	Alaska			First and Best				Early Washington			
Number of vines examined	50			150				25			
Date Examined	No. eggs Laid	Temperature Max.	Temperature Min.	Date Examined	No. eggs Laid	Temperature Max.	Temperature Min.	Date Examined	No. eggs Laid	Temperature Max.	Temperature Min.
June 7, '32	36	70	38	June 8	0	78	35	July 6	3	78	44
8	12	78	35	9	12	77	48	7	24	88	44
9	53	77	48	10	18	79	57	8	87	83	50
10	53	79	51	11	38	86	55	9	156	87	46
11	60	86	55	12	158	88	48	10	200	75	61
12	115	88	48	13	347	71	52	11	69	77	45
13	117	91	52	14	861	89	58	12	79	83	40
14	204	89	58	15	0	65	58	13	125	72	55
15	0	65	58	16	598	71	47	14	12	71	53
16	71	71	47	17	998	75	43	15	94	78	49
17	136	75	43	18	784	80	45	16	310	83	42
18	149	80	45	19	595	71	54	17	299	77	46
19	146	71	54	20	970	86	53	18	538	75	52
20	221	86	53	21	1139	94	60	19	348	78	40
21	348	94	60	22	1405	90	62	20	316	86	42
22	294	90	62	23	982	86	57	21	575	97	52
23	186	86	57	24	563	87	46	22	853	97	52
24	58	87	46	25	407	84	48	23	497	91	54
25	54	84	48	26	266	88	45	24	360	82	51
26	18	88	45	27	202	83	47	25	138	84	54
27	42	83	47	28	75	86	49	26	63	90	43
28	15	86	49	29	36	85	51	27	42	99	45
29	6	85	51	30	17	83	45	28	8	88	54
30	1	83	45	July 1	3	91	49	29	1	80	45
July 1	12	91	49	2	4	83	57	30	1	77	46
2	7	83	57	3	0	70	56				
3	0	70	56								

Plate 8 shows on further study that individual plantings of Alaska peas were suitable for oviposition for a period of 8 to 30 days, depending on the date they were seeded. Table 11 presents a summary of this experiment. This table shows clearly the period over which a planting of peas must be protected if they are to escape weevil damage.

Table 11

Length of Time Alaska Peas are Suitable for Egg Deposition of the Pea Weevil *Bruchus pisorum* L. at Moscow, Idaho, 1933.

Planted	First Egg Laid	Last Egg Laid	Total Period Over Which Eggs Were Laid
April 6	June 12	July 11	30 days
13	15	12	28 "
20	15	14	30 "
27	17	16	30 "
May 4	21	11	21 "
11	25	17	23 "
18	27	25	29 "
25	July 4	20	17 "
June 1	9	27	19 "
8	15	22	8 "
15	21	31	11 "

A similar study carried on during 1932 on individual pods on vines of Early Washington peas demonstrated that they were used for egg laying from six to 18 days. Observations and measurements showed that the pods most frequently used, the ones on which the greatest number of eggs are usually laid, are those which have nearly reached their maximum size, but which are still in the process of growth. Table 12 shows a few typical examples from this study. The number of eggs laid per pod depends largely on the number of weevils on the peas and the number of pods available for deposition. One pod about two inches long picked from a very badly infested patch near Moscow, Idaho, had 116 eggs laid on its surface. Table 9 gives a summary of

Table 12

Daily Egg Deposition on 20 Pea Pods (Variety-Early Washington, Moscow, Idaho, 1952.

Pod No.	7/9	7/10	7/11	7/12	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	Total No. of Eggs per Pod
	Date on which eggs were deposited																				
1									6	5	6	5	5	14	1						42
2								5	5	4	9	0	12	11	0	1					47
3										2	0	5	7	9	11	6					40
4			4	0	7	0	0	4	4	11	4	16	9	10	0	7					76
5			3	0	6	0	0	0	14	18	15	12	6	19	3	9					105
6	7	3	4	0	0	0	0	13	10	18	0	0	10	4	0	5	0	2			76
7								2	2	4	2	8	3	8	8	0	7				44
8								6	3	0	2	1	4	0	0	10	0	1	1		28
9	3	4	3	0	3	0	0	14	8	12	4	0	3	13	13	5					85
10								8	7	15	0	1	21	13	5						70
11	6	0	0	0	5	0	0	4	0	9	12	18	16	17	8	2					97
12										6	5	3	1	0	9	11	8	8			51
13							7	3	1	3	4	5	0	11	0	1	3				38
14								5	0	12	14	13	2	5							51
15								8	0	5	0	0	14	2	8	6	2	1			46
16				6	0	0	5	3	8	0	4	0	2	15	16	8					67
17										1	7	10	28	16	2	10	3	0	2		79
18				10	4	0	2	7	8	3	7	2	1	0	6	6					56
19									3	7	0	6	11	11	15	0	1	2	2		58
20				5	3	6	0	4	12	21	10	1	13	13	0	21	13	1	0	3	126
Max. Temp.	87	70	72	80	68	71	78	83	76	72	72	81	94	92	85	86	78	86	93	80	

the number of eggs laid on three varieties of peas. A photograph of a pea weevil ovipositing is shown in Plate 9.

Incubation period. The incubation period of the eggs of the pea weevil depends greatly on the temperature. Skaife (1918), working in South Africa, reports a variation of from 16-21 days and Korab (1927), working in Russia, found the incubation period to last from 6-10 days. The results of a large number of observations made at Moscow, Idaho, show that this stage varied from 6-14 days with an average of about nine days. The studies were carried on during June and July when the temperature for June averaged 75.9° F. and for July 78.5° F.[3] Table 16 presents the results of this study in detail and Tables 14 and 15 present the summaries.

These results were obtained by marking eggs laid on the pods of the staked vines as in the previous experiment. A circle of black India ink was made about each egg on which data were desired. The ink remained visible throughout the season and caused no injury to the pod if care was used in its application. Plate 10 shows ink marked eggs. Occasionally weevils would lay other eggs within the circle about the egg under observation. If this occurred, all the eggs were rubbed off unless the egg under observation could be told with absolute certainty.

Larval stage. The newly hatched larva of the pea weevil can be readily detected by its light color and wrinkled appearance. Entrance to the interior of the pod is gained by boring through the chorion and into the pod through the underside of the egg. The small round entrance hole can easily be seen when the shell has been scraped away. At times the larva does not

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[3]Climatological Data, Idaho Section, United States Department of Agriculture, Weather Bureau.

work its way into the interior of the pod at once but instead mines about in the pod. Once inside the pod, the tiny larva soon penetrates the seed. A small dark spot forms over the place where the larva enters the pea, as shown in Plate 11. Oftentimes many larvae try to enter the same pea, for as high as 60 stings have been counted on a single pea. The relation of the incubation period to the development of the seed is interesting, for even though the egg is laid when the pod is very small, by the time the egg has hatched the peas have attained a goodly size. Finally, after gaining entrance to the pea the larva feeds near the seed coat until about one third grown and the seed has begun to harden, after which it works its way toward the center. A large portion of the contents of the pea has been eaten away by the time the larva has completed its growth. Plate 12 shows at approximately weekly intervals the injury resulting from the feeding of the larva. The larval stage lasted about 40 days in the vicinity of Moscow, Idaho. The mature larva usually cuts a small round emergence hole to the exterior of the pea, about two days before it pupates, to facilitate the escape of the adult.

More than one larva oftentimes succeeds in gaining entrance to the pea, but on only one occasion have two adults been observed to complete their development in the same pea. This occurrence has never before been reported in the literature. Usually, however, only one larva is able to complete its development and emerge, for, as has been pointed out by other workers, the extra larvae oftentimes die soon after they penetrate the seed, but in other cases the competing individuals are not so considerate, for at times two or even more develop until they become so large that their feeding tunnels meet and the larvae fight for the possession of the food supply. Both individuals are often killed in the fight, but in still other cases two insects complete their development inside the same pea but only one comes out alive. Repeated observations show that one larva develops faster than its rival, pupates, and transforms, only to become the victim of its slower developing rival, which then develops to maturity. Plate 13 shows several peas in which more than one individual has tried to develop.

Eggs marked as in the previous experiment were allowed to hatch and the larvae allowed to develop to determine the length of the remaining stages in the life cycle. The weevil-infested seeds were allowed to remain on the vine until they had ripened. Each marked pod was removed and shelled into a compartment of the development tray. These were kept in a field insectary building and examined daily for the appearance of the "emergence window." When this appeared, the end of the larval stage was known to be near, so the window was opened to determine the exact day of pupation. If this procedure was followed, the larva was usually in the pre-pupa stage when the pea was opened and the individual seemed to be unaffected by the abnormal situation.

The average length of the larval stage was 41 days in one series, the maximum 56 days, and the minimum 28 days. A summary of the results is presented in Tables 14 and 15 and in detail in Table 16. This insect, developing as it does within the pea, presents difficulties that make it impossible to conduct a series of measurements on the same individual to determine the number of molts. This information was obtained, however, by splitting peas at two-day intervals from peas grown in one locality and measuring the head capsules of the larvae collected from the split peas. The head capsules of 25 larvae collected on each of these days were measured to determine the molts of the weevil. The results obtained seemed quite clean-cut, for the measurements grouped themselves logically into four classes, denoting three molts and four instars in the larval development. The average widths of the head capsules for the instars as obtained by this method were: first instar, 0.1420 mm.; second instar, 0.3458 mm.; third instar, 0.6353 mm.; and the fourth instar, 0.9125 mm. The complete summary of these results is given in Table 13.

Table 13

Development of the Larva of the Pea Weevil by Instars, Moscow, Idaho, 1932.

Date	Instar				Average Daily Head Capsule Measurements		
	1st	2nd	3rd	4th	Average	Maximum	Minimum
June 28, '32	25				0.1367 mm.	0.1430 mm.	0.1287 mm.
30	25				.1338	.1430	.1287
July 2	25				.1436	.1716	.1287
4	25				.1493	.1573	.1287
6	24	1			.1468	.1573	.1287
8	25	0			.1678	.3718	.1287
10	14	11			.2593	.3888	.1287
12	2	21	2		.3512	.3861	.1280
14	8	15	2		.2938	.6480	.1287
16		9	16		.5189	.6578	.3146
18		7	18		.5472	.6768	.3024
20			25		.6395	.6730	.6006
22			25		.6581	.6912	.6048
24			24	1	.6484	.9370	.5863
26			25	0	.6470	.7668	.6336
28			25	0	.6412	.7150	.5720
30			19	6	.6973	1.0224	.5904
Aug. 1			11	14	.8107	1.0224	.5720
3			15	10	.7410	.9798	.5328
5			12	13	.7774	.9372	.5472
7			7	18	.8313	.9372	.5900
9			3	22	.8724	1.0224	.5964
Av. instar head capsule measurements	.1420 mm.	.3458 mm.	.6353 mm.	.9125 mm.			

A study of this table shows that during the crop season of 1932 the insect spent approximately 12 days in the first instar, 6 to 8 in the second, 12 to 14 in the third, and 10 to 12 days in the fourth instar. Two days before the end of the last instar, in most cases, the larva cuts its way to the seed coat and then becomes stiff and motionless in the pre-pupa stage. The seed coat is also partially cut by the larva before the pre-pupa stage to permit the emergence of the adult.

The pupa. The larva pupates within the pea with its head toward the emergence hole. The average length of the stage during 1932 was 15 days, the maximum 27 days, and the minimum 8 days (Tables 14, 15 and 16.) The length of the stage was determined by opening the emergence hole one day after it was first observed. The date of pupation and transformation could then be easily observed.

Length of the life cycle. Table 14 presents a summary of the length of the stages in the life cycle of 548 individuals reared during the crop season of 1932 and Table 15 presents a summary of these data from 231 complete records obtained during the summer of 1933. The detailed results of Series III reared during the summer of 1933 are presented to demonstrate the type of data collected for each individual reared. A study of Table 14 shows that the life cycle was completed in an average of 65 days. The slowest developing individual completed its life cycle in 82 days and the fastest developing individual completed its development in 50 days. The agreement between the three series studied during 1932 is close. These data, however, differ considerably from the data obtained by the same technique during 1933. During this season the average length of the life cycle for the 231 individuals reared was 53 days. The maximum developmental time was 72 days and the minimum was 45 days. The difference is undoubtedly due to the favorable conditions existing during 1933 that favored both the pea plant and the pea weevil.

These detailed studies were paralleled by field examinations. Every two days throughout the development of the weevil during 1932 and 1933, 250 weevil-infested peas were split open from two different plantings of peas. Plates 14, 15, 16 and 17 and Tables 17, 18, 19 and 20 present the results of this study in detail.

Table 14

Summary of the Life History Data on the Pea Weevil (Bruchus pisorum L.) at Moscow, Idaho, 1932.

Alaska - 76 Individuals Reared

Length of the stages	Stages			
	Egg	Larva	Pupa	Life Cycle
Maximum	14 days	50 days	18 days	75 days
Minimum	7 "	38 "	8 "	60 "
Average	10.3 "	42.7 "	13.5 "	66.3 "
Standard deviation	1.62 "	3.18 "	1.59 "	3.76 "
Modal class	10 "	43 "	14 "	67 "
First observed	June 7	June 20	July 31	
Last observed	June 21	June 29	Aug. 13	

Early Washington - 72 Individuals Reared

Length of the stages	Stages			
	Egg	Larva	Pupa	Life Cycle
Maximum	13 days	45 days	27 days	81 days
Minimum	6 "	33 "	16 "	61 "
Average	8.5 "	38.3 "	22.6 "	69.4 "
Standard deviation	1.53 "	2.84 "	2.85 "	4.84 "
Modal class	8 "	37 "	25 "	70 "
First observed	July 7	July 16	Aug. 24	
Last observed	July 24	July 31	Sept.10	

Table 14 (Cont.)

First and Best - 400 Individuals Reared

Length of the stages	Stages			
	Egg	Larva	Pupa	Life Cycle
Maximum	13 days	56 days	18 days	82 days
Minimum	8 "	28 "	10 "	50 "
Average	8.7 "	41.7 "	13.7 "	64.1 "
Standard deviation	1.46 "	3.48 "	1.07 "	4.04 "
Modal class	9 "	41 "	14 "	65 "
First observed	June 9	June 21	July 27	
Last observed	June 25	July 2	Aug. 17	

Table 15

Summary of Life History Data on the Pea Weevil (Bruchus pisorum L.) at Moscow, Idaho, 1933.

Series I - 19 Individuals Reared in Alaska Peas

Length of the stages	Stages			
	Egg	Larva	Pupa	Life Cycle
Maximum	14 days	51 days	16 days	72 days
Minimum	5 "	31 "	8 "	48 "
Average	9.8 "	37.3 "	10.7 "	57.5 "
Standard deviation	2.16 "	5.98 "	2.00 "	6.06 "
First observed	June 16,1933	June 26,1933	Aug. 4,1933	
Last observed	July 6,1933	July 14,1933	Aug. 31,1933	

Series II - 101 Individuals Reared in Alaska Peas

Length of the stages	Stages			
	Egg	Larva	Pupa	Life Cycle
Maximum	11 days	41 days	17 days	65 days
Minimum	6 "	25 "	9 "	45 "
Average	8.5 "	34.8 "	12.2 "	54.9 "
Standard deviation	1.03 "	2.83 "	1.79 "	3.72 "
Modal class	9 "	33 "	12 "	53 "
First observed	June 27,1933	July 5,1933	Aug. 11,1933	
Last observed	July 16,1933	July 22,1933	Aug. 28,1933	

Table 15 (Cont.)

Series III - 111 Individuals Reared in Alaska Peas

Length of the stages	Stages			
	Egg	Larva	Pupa	Life Cycle
Maximum	11 days	40 days	16 days	65 days
Minimum	5 "	29 "	8 "	47 "
Average	9.1 "	32.1 "	11.1 "	52.3 "
Standard deviation	1.22 "	1.69 "	1.42 "	2.65 "
Modal class	9 "	31 "	11 "	52 "
First observed	July 1,1933	July 6,1933	Aug. 7,1933	
Last observed	July 12,1933	Aug. 20,1933	Sept. 3,1933	

Table 16

Life History of the Pea Weevil (Bruchus pisorum L.) Reared in Alaska Peas at Moscow, Idaho, 1933.

(Series III)

Record No.	Egg Laid	Egg Hatched	No. Days in egg stage	Larva pu-pated	No. Days larval stage	Pupa trans-formed	No. Days pupa stage	Total Days in life cycle
1	7-1	7-12	11	8-11	30	8-21	10	51
2	"	"	11	8-12	31	8-22	10	52
3	"	"	11	8-11	30	"	11	52
4	"	7-11	10	"	31	8-20	9	50
5	"	"	10	"	31	8-22	11	52
6	"	7-12	11	8-12	31	8-23	11	53
7	"	"	11	8-15	34	8-28	13	58
8	"	7-11	10	8-11	31	8-20	9	50
9	"	"	10	"	31	8-21	10	51
10	"	"	10	8-12	32	8-23	11	53
11	"	"	10	"	32	8-22	10	52
12	"	"	10	8-11	31	8-23	12	53
13	"	"	10	8-12	32	"	11	53
14	"	"	10	8-14	34	8-26	12	56
15	"	"	10	"	34	8-24	10	54
16	"	"	10	8-12	32	8-23	11	53
17	"	"	10	8-15	35	8-27	12	57
18	"	7-12	11	8-13	32	8-24	11	54
19	"	"	11	8-13*	32	8-26	13	56
20	"	"	11	8-14	33	8-25	11	55
21	"	7-11	10	"	34	"	11	55
22	"	"	10	8-15	35	8-28	13	58

Table 16 (Cont.)

Record No.	Egg Laid	Egg Hatched	No. Days in egg stage	Larva pupated	No. Days larval stage	Pupa transformed	No. Days pupa stage	Total Days in life cycle
23	7-1	7-11	10	8-13	33	8-24	11	54
24	"	"	10	8-11	31	8-20	9	50
25	"	"	10	8-12	32	8-21	9	51
26	"	7-12	11	8-13	32	8-23	10	53
27	"	"	11	8-12	31	8-22	10	52
28	"	7-11	10	8-15	35	8-27	12	57
29	"	7-12	11	8-11	30	8-22	11	52
30	"	"	11	8-12	31	8-23	11	53
31	"	7-6	5	8-7	32	8-17	10	47
32	"	"	5	8-8*	33	8-19	11	49
33	"	7-8	7	8-12	35	8-22	10	52
34	"	"	7	8-11	34	8-23	12	53
35	"	"	7	8-12	35	8-24	12	54
36	"	7-11	10	8-11	31	8-20	9	50
37	7-2	7-12	10	8-12	31	8-22	10	51
38	"	"	10	8-13	32	8-24	11	53
39	"	7-11	9	8-11	31	8-20	9	49
40	"	"	9	8-13	33	8-25	12	54
41	7-3	7-12	9	8-13	32	"	12	53
42	"	"	9	8-13*	32	8-24	11	52
43	"	"	9	8-12	31	8-21	9	49
44	"	"	9	8-14	33	8-23	9	51
45	"	7-13	10	"	32	"	9	51
46	"	"	10	8-14*	32	8-22	8	50
47	"	"	10	8-12	30	8-23	11	51
48	"	"	10	8-12*	30	8-28	16	56
49	"	"	10	8-12	30	8-23	11	51
50	"	7-12	9	8-13	32	8-24	11	52
51	"	"	9	8-11	30	8-20	9	48
52	"	"	9	8-14	33	8-24	10	52
53	"	"	9	8-12	31	3-23	11	51
54	"	"	9	8-13	32	8-28	15	56
55	"	7-11	8	8-11	31	8-21	10	49
56	"	7-12	9	8-13*	32	8-24	11	52
57	"	"	9	8-15	34	8-25	10	53
58	"	"	9	8-13	32	8-24	11	52
59	"	"	9	8-14	33	8-26	12	54
60	"	"	9	"	33	"	12	54
61	"	"	9	8-13	32	8-24	11	52
62	"	7-11	8	8-12	32	8-22	10	50
63	"	"	8	8-14	34	8-26	12	54
64	"	7-13	10	8-12	30	8-22	10	50
65	"	7-12	9	8-11	30	8-21	10	49

Table 16 (Cont.)

Record No.	Egg Laid	Egg Hatched	No. Days in egg stage	Larva pu-pated	No.Days larval stage	Pupa trans-formed	No.Days pupa stage	Total Days in life cycle
66	7-3	7-12	9	8-13	32	8-23	10	51
67	"	"	9	8-10*	29	8-20	10	48
68	"	"	9	8-10	29	"	10	48
69	"	"	9	8-14	33	8-25	11	53
70	"	"	9	8-15*	34	8-27	12	55
71	"	"	9	8-12	31	8-22	10	50
72	"	"	9	8-14	33	8-25	11	53
73	"	"	9	8-10	29	8-20	10	48
74	"	"	9	8-13	32	8-24	11	52
75	"	"	9	8-21	40	9-6	16	65
76	"	"	9	8-17	36	8-29	12	57
77	"	"	9	8-13	32	8-24	11	52
78	"	"	9	8-12	31	8-22	10	50
79	"	7-11	8	"	32	8-23	11	51
80	"	"	8	8-11	31	8-21	10	49
81	"	"	8	8-15	35	8-27	12	55
82	"	7-12	9	8-12	31	8-23	11	51
83	"	"	9	8-10	29	8-20	10	48
84	"	"	9	8-15*	34	8-28	13	56
85	"	"	9	8-12	31	8-22	10	50
86	"	"	9	8-13	32	8-24	11	52
87	"	"	9	8-12	31	8-23	11	51
88	7-4	7-13	9	8-15	33	8-25	10	52
89	"	7-12	8	8-16	35	8-28	12	55
90	"	7-13	9	8-15	33	8-27	12	54
91	7-5	7-14	9	8-14	31	8-26	12	52
92	"	"	9	"	31	"	12	52
93	"	"	9	8-17	34	8-29	12	55
94	"	"	9	8-14	31	8-26	12	52
95	"	"	9	8-16	33	8-28	12	54
96	7-6	7-13	7	8-12	30	8-23	11	48
97	"	7-12	6	8-14	33	8-26	12	51
98	"	7-14	8	"	31	8-25	11	50
99	"	"	8	"	31	"	11	50
100	"	"	8	8-15	32	8-28	13	53
101	7-7	7-15	8	"	31	8-26	11	50
102	"	"	8	"	31	8-27	12	51
103	"	"	8	8-17	33	8-29	12	53
104	"	"	8	8-17*	33	8-29	12	53
105	"	"	8	8-18	34	9-1	14	56
106	"	"	8	"	34	8-31	13	55
107	"	"	8	8-17	33	8-30	13	54

Table 16 (Cont.)

Record No.	Egg Laid	Egg Hatched	No. Days in egg stage	Larva pu-pated	No.Days larval stage	Pupa trans-formed	No.Days pupa stage	Total Days in life cycle
108	7-10	7-16	6	8-15	30	8-27	12	48
109	"	7-17	7	8-17*	31	8-30	13	51
110	"	7-18	8	8-20*	33	9-2	13	54
111	7-12	7-19	7	8-20	32	9-3	14	53

*Pupated outside pea.

Table 17

Development of the Pea Weevil (<u>Bruchus</u> <u>pisorum</u> L.) in Early Planted Alaska Peas at Moscow, Idaho, 1932.

Date Examined	Larvae	Pupae	Adults	Adults Emerged
August 7	250			
9	247	3		
11	241	9		
13	239	11		
15	225	25		
17	211	39		
19	183	67		
21	142	100	8	
23	125	121	4	
25	74	161	15	
27	82	150	18	
29	59	156	35	
31	54	141	54	1
Sept. 2	61	127	61	1
4	68	127	55	0
6	40	143	66	1
8	43	113	90	4
10	32	103	110	5
12	32	73	129	16
14	19	72	140	19
16	16	69	144	21
18	16	48	158	28
20	15	74	101	61
22	20	66	96	68
24	12	47	119	74
26	10	26	134	80
28	15	47	113	75
30	7	22	122	99
Oct. 2	18	37	111	84
4	3	19	134	94
6	4	31	118	47
8	12	23	96	120
10	18	23	121	85
12	10	31	60	140
14	2	20	37	191
16	9	14	24	193

Table 18

Development of the Pea Weevil (Bruchus pisorum L.) in Volunteer First and Best Peas, Moscow, Idaho, 1932.

Date Examined	Larvae	Pupae	Adults	Adults Emerged
July 27	250			
29	241	4		
31	249	1		
Aug. 2	223	27		
4	202	48		
6	169	81		
8	134	114	2	
10	130	115	5	
12	115	128	7	
14	88	153	9	
16	30	173	47	
18	10	162	77	1
20	21	125	103	1
22	36	125	89	11
24	18	96	126	10
26	6	74	145	25
28	10	46	161	43
30	5	46	143	56
Sept. 1	5	38	158	49
3	3	19	171	57
5	4	14	166	66
7	9	18	145	78
9	2	12	143	93
11	1	6	167	76
13	2	3	143	102
15	2	2	137	109
17	2	5	169	74
19	2	3	93	152
21	2	3	13	232
23	2	1	13	234
25	2	5	21	218
27	6	0	20	228
29	2	2	12	235
Oct. 1	1	0	15	234
3	1	0	19	230
5	0	2	31	217
7	0	0	19	231
9	1	1	20	228
11	2	1	40	207
13	1	0	4	245
15	0	2	3	245

Table 19

Development of the Pea Weevil (Bruchus pisorum L.) in Early Planted Alaska Peas, Moscow, Idaho, 1933.

Date Examined*	Larvae	Pupae	Adults	Adults Emerged	Total Dead
Aug. 11	247	3			8
13	246	4			2
15	243	7			3
17	224	26			11
19	189	61			30
21	166	84			11
23	174	75	1		36
25	144	103	3		37
27	109	136	5		18
29	96	121	31	2	22
31	63	148	39	0	16
Sept. 2	78	123	49	0	20
4	46	130	72	2	25
6	54	144	47	5	14
8	108	109	27	7	23
10	35	85	82	48	22
12	40	86	79	45	28
14	9	50	166	25	6
16	32	77	121	20	26
18	19	81	123	27	14
20	19	77	100	54	18
22	4	41	130	75	11
24	23	73	96	58	6
26	12	45	128	65	6
28	27	66	88	69	25
30	9	54	100	87	22
Oct. 2	5	29	95	121	7
4	15	68	74	93	45
6	9	37	84	120	18
8	11	54	73	111	35
10	3	37	87	123	37
12	8	62	85	95	64
14	3	19	86	142	27

*250 living individuals examined each date.

Table 20

Development of the Pea Weevil (Bruchus pisorum L.) in Late Planted Alaska Peas at Moscow, Idaho, 1933.

Date Examined*	Larvae	Pupae	Adults	Adults Emerged	Total Dead
Aug. 19	235	15			5
21	227	23			4
23	202	48			16
25	120	130			3
27	109	141			10
29	129	121			14
31	76	174			6
Sept. 2	90	160			4
4	58	182	10		9
6	42	186	22		7
8	41	116	93		293
10	30	141	78	1	25
12	29	148	72	1	7
14	26	102	120	2	8
16	12	90	148	0	3
18	8	71	161	10	3
20	6	74	155	15	2
22	6	80	119	45	4
24	11	67	132	40	8
26	10	67	142	31	11
28	11	104	121	14	14
30	8	51	134	57	13
Oct. 2	9	47	154	40	5
4	16	81	92	62	35
6	6	57	114	83	20
8	9	61	110	70	29
10	5	46	86	114	17
12	5	35	122	88	28
14	5	37	128	80	24
16	6	55	63	106	20

*250 living weevils examined each date.

A study of the graphs shows the influence that temperature and rainfall have on the development of the pea weevil. A cursory examination shows that the weevils start emerging from the peas shortly after they have reached the adult stage, but that immediately following a rainstorm the weevils come out in the largest numbers. This is probably due to the fact that the rain facilitates the escape of the weevils from the tightly closed pods and peas. Splitting records were discontinued when cold weather set in for further development was impossible. Each year there were a few of each stage in the life cycle still in the peas when the observations were discontinued.

Natural enemies. Several insects are described in the literature as parasites of the pea weevil. Skaife (1918) reared *Bruchocida orientalis* Cwfd. from the pea weevil. *Bruchobius laticollis* Ashm. was listed by Pierce (1908) and by Cushman (1911) as a parasite of the pest. Korab (1927) working in Russia found the egg parasite *Bruchoctonus senex* Grese infesting as high as 60 per cent of the eggs of the insect. None of these species was found at Moscow, Idaho. Two species, however, one of them new, were reared. *Microdontomerus anthonomi*[4] Cwfd. and *Eupteromalus*[4] sp. were found as larvae or pupae inside the pea seeds and, in every case, on the outside of a dead larva or pupa. The larvae appeared to be mature, for in most cases they pupated readily and emerged as adults. Both of these parasites were very scarce, for only three or four have been found each season. No egg parasites were found. A small red mite belonging to the family *Erythraeidae* and the genus *Atomus*[5] fed extensively on the eggs of the wee-

[4]Identified by C. F. W. Muesebeck of the United States National Museum.
[5]Identified by H. E. Ewing of the United States National Museum.

vil during 1932, but did not appear in any numbers during 1934.

Effect of the pea weevil on the seed pea. Weevil-infested peas, in addition to being undesirable for human food, are also rendered unfit for agricultural purposes. Some controversy exists in the literature and among pea growers with reference to the influence that the presence of pea weevils in seed peas has on their germination.

Parallel with the developmental splitting records made during 1933, pea samples were fumigated at weekly intervals from the time the peas began to ripen until the emergence of the weevils had begun. These fumigated samples were then tested for germination. The results of this investigation are presented in Table 21. An examination of this table shows very clearly that the germination of weevil-infested seed peas depends on the extent to which the pea weevil has developed when the peas are fumigated. Peas picked immediately after they have completed their development and fumigated at once lose little of their viability, but the percentage germinating rapidly decreases as the weevil develops. These results corroborate the work of Zavitz and Lochhead (1903) in Canada, who found that early harvesting and fumigation increase the per cent of peas germinating. These data also explain the many conflicting statements in the literature as to the damage done by the weevil to the germ of the pea.

Table 21

Influence of the Development of the Weevil on the Germination of Weevily Peas, Moscow, Idaho, 1933.

Sample Number	Picked and Fumigated	Germination[1] Per Cent	Development of Weevil When Fumigated % Larvae	% Pupae	% Adults	% Emerged
1	July 20	0.00*	100			
2	" 27	98.00	100			
3	Aug. 3	77.00	100			
4	" 10	50.00	98.8	1.2		
5	" 17	16.50**	89.6	10.4		
6	" 24	1.00***	69.6	30.0	0.4	
7	" 31	3.50***	25.2	59.2	15.6	
8	Sept. 7	4.00***	21.6	57.6	18.8	2.0

* "All terribly decayed." Peas hardened, but still green when picked.
** "Very badly decayed."
***"Most all seeds decayed."
[1]All germination tests made by Bureau of Plant Industry Seed Testing Laboratory at Corvallis, Oregon. Notations from the Report of the Seed Testing Laboratory.

Pea growers are too well acquainted with the fact that "buggy" peas weigh less than sound peas. It was advantageous, during the summer of 1933, to make weighings at two-day intervals on a sample of weevil-infested peas and a sample of sound peas picked from the same field. The peas used were threshed just as soon as the pods on the vines had ripened to the place where hand threshing was possible. Table 22 presents the results of this study. The weevil-infested peas lost 22.2 per cent of their original weight while the sound peas lost but 1.1 per cent of their original weight.

Table 22

Loss in Weight of Peas Due to the Feeding of the Pea Weevil (*Bruchus pisorum* L.), Moscow, Idaho, 1933
Series I

Date Weighed	Weevily Peas		Sound Peas	
	Weight in Grams	Total Loss in Grams	Weight in Grams	Total Loss in Grams
July 26, 1933	2295	0	2319	0
28	2209	86	2316	3
30	2160	135	2314	5
Aug. 1	2108	187	2309	10
3	2023	272	2304	15
5	1968	327	2308	11
7	1926	369	2311	8
9	1880	415	2308	11
11	1852	443	2302	17
13	1836	459	2297	22
15	1822	473	2292	27
17	1809	486	2287	32
19	1803	492	2287	32
21	1806	489	2290	29
23	1804	491	2291	28
25	1797	496	2290	29
27	1793	502	2290	29
29	1786	509	2290	29
31	1791	504	2292	27
Sept. 2	1788	507	2293	26
4	1782	513	2291	28
6	1780	515	2291	28
8	1780	515	2291	28
10	1784	511	2292	27

Factors Influencing the Abundance of the Weevil

Certain factors have been observed during the course of this study which operate to maintain very high adult weevil populations. The elimination of these factors presents many serious difficulties but their accomplishment would mean the elimination of the pea weevil problem.

Methods

Harvest loss and the shattering of ripe peas constitute the most important source from which the pea weevils that infest the crop are recruited. The amoung of the loss was studied by picking up all the peas lost on six ten-foot square plots in each field studied. The general localities in which the samples were to be picked, such as the north edge of the field, at the top of a hill, or in a valley, were chosen in order to insure as uniform a set of locations as possible in each of the fields. The exact location of the plot in each locality was decided by chance. This was accomplished by having one of the boys helping to gather the peas close his eyes and rotate until he had lost his sense of direction, after which, still with closed eyes, he would throw a stake as far as possible. The ten-foot plot was then staked out about the locality where the stake fell. The number of plots picked for the acreage sampled was small in number, but because of the harvesting methods in use it seemed best to use fewer large plots rather than a larger number of smaller plots. The results seemed uniform and accurate, for the total yield plus the total loss was in general agreement on all the fields investigated, and furthermore the amount of loss suffered by the same farmers over a two-year period was in agreement. The loss per plot was figured by weighing and counting the peas collected.

The study of the effect of planting weevil-infested peas was carried out in cages 3 feet x 4 feet x 3 feet 6 inches. The peas were planted in rows $3\frac{1}{2}$ inches deep beneath these cages. All the weevils that emerged were retained in the cages.

Results

Field shatter. Field shatter -- the shelling out of ripe peas on the ground -- is due primarily to faulty harvesting methods and to climatic factors. Larson (1931) has already pointed out the serious results of careless harvesting in the Willamette Valley in Oregon and has indicated that burning the debris on the field would kill almost 100 per cent of the weevils in shattered peas. This investigation pointed out in this connection also that in three years the weevils escaping from shattered peas increase the hibernating populations to such an extent that the peas grown the third year are practically all infested. Korab (1927) found that in Russia emergence from shattered peas was of little import to the pea growers, for they are unable to survive the winters out-of-doors in the pea growing sections of that country. The problem of field shatter was found to exist and to be of a very serious nature in the Palouse Area of Idaho and Washington.

The maximum loss per acre was found to be 50 per cent of the possible yield on a field harvested by the combine method, in which the peas actually harvested averaged 690 pounds per acre. The minimum loss, which loss also occurred on a combined field, was 7 per cent on a field from which 1,428 pounds of peas were harvested per acre.

Two different methods of harvesting peas are in general use in the territory and several fields harvested by each method were sampled to determine if any one of the harvesting methods was superior. A summary of this study carried on during the fall of 1931 and 1932 is presented in Table 23 and the results in detail are presented in Tables 24, 25 and 26. The average loss for the 20 fields examined was 33 per cent of the possible yield. Loss on 11 fields harvested by the combine method had amounted to 29 per cent, on six fields harvested by the mower, rake and stationary thresher 33 per cent, and on the fields harvested and threshed by other methods the loss amounted to 38 per cent. Losses were not so heavy in 1932 (Table 23). The loss on 12 fields

Table 23

Summary of Loss in Peas and Harvesting Methods

Harvesting Method	1931 No.fields Examined	1931 No.plots Examined	1931 Per Cent Loss	1932 No.fields Examined	1932 No.plots Examined	1932 Per Cent Loss
Combined	11	62	29	12	72	11.5
Mowed and threshed	6	32	32	5	30	21.6
Mowed, raked into windrows and combined	2	10	38	2	12	15.2

harvested by the combine method was 11.5 per cent of the possible yield, on five fields mowed, raked and threshed the loss was 21.6 per cent, while on two other fields harvested by other methods the loss amounted to 15.2 per cent.

Much of this loss is due to careless harvesting methods as shown by Table 27. An inspection of this table shows that those individuals who had the lightest harvest loss in 1931 had the lightest loss during 1932 and those that had the heavy losses during 1931 also had heavy losses during 1932.

Table 24

Harvest Loss and Weevil Infestation (Peas Combined), Moscow, Idaho, 1951

Ranch	Variety of Peas	Acres	Date Harvested	Yield in Pounds Per Acre	Loss in Pounds Per Ac.	Per Cent Loss	No. of Peas Lost Per Acre	Per Cent Infested	No. of Weevily Peas Per Acre	No. of Plots Ex.
7	First & Best	45	8/15/1951	1656	404	20	1,169,045	50.0	584,522	6
8	Alaska	15	8/20/1951	998	235	19	687,723	68.0	467,541	6
9	Alaska	188	8/25/1951	1794	625	26	1,559,226	0.5	8,108	5
10	Alaska	200	8/25/1951	1518	492	24	1,177,862	2.2	25,442	5
11	Alaska	300	8/ 7/1951	966	799	47	1,804,205	5.2	93,097	6
12	Alaska	18		1104	836	43	2,575,802	56.3	1,450,176	5
13	Alaska	530		1080	484	31	1,058,944	0.9	9,531	6
14	First & Best	96	8/10/1951	1037	457	31	1,203,911	14.0	168,548	5
15	Alaska	70		690	693	50	1,609,053	18.5	297,675	6
16	Alaska	170	8/10/1951	1428	116	7	334,976	5.7	19,094	6
17	Alaska	155	8/ 9/1951	1595	388	22	852,054	0.6	5,368	6

Table 25

Harvest Loss and Weevil Infestation (Peas Mowed and Threshed)

Ranch	Variety of Peas	Acres	Date Harvested	Yield in Pounds Per Acre	Loss in Pounds Per Ac.	Per Cent Loss	No. of Peas Lost Per Acre	Per Cent Infested	No. of Weevily Peas Per Acre	No. of Plots Ex.
1	Alaska	25	8/ 1/1951	1375	442	24	1,240,421	58.8	729,368	6
2	Alaska	28	8/18/1951	731	396	35	1,137,787	4.0	45,739	5
3	Alaska	55	8/ 4/1951	1104	845	43	2,141,357	2.2	46,233	5
4	Bluebell	45	8/21/1951	690	444	38	911,798	0.2	1,469	5
5	Alaska	25	8/ 7/1951	1573	510	24	1,160,874	7.4	85,905	6
6	Bluebell	6	8/15/1951	690	166	19	340,639	12.0	40,877	5

Table 26

Harvest Loss and Weevil Infestation (Other Harvesting Methods), Moscow, Idaho, 1951

Ranch	Variety of Peas	Acres	Date Harvested	Yield in Pounds Per Acre	Loss in Pounds Per Ac.	Per Cent Loss	No. of Peas Lost Per Acre	Per Cent Infested	No. of Weevily Peas Per Acre	No. of Plots Ex.
18*	Alaska	90	9/20/1951		869		2,194,144	30.2	662,612	6
19**	Canadian	46	8/10/1951	966	319	32	1,065,813	6.2	67,320	4
20**	Alaska	70	8/16/1951	676	531	44	1,173,942	3.2	37,566	6

* Vines raked up and stacked.
**Mowed, raked into windrows and combined.

Table 27

Comparison of Harvest Loss and Weevil Infestation for 1931 and 1932

Ranch	1931 Harvesting Method	1931 % Infested	1931 Yield in Lbs. Per Acre	1931 Loss in Lbs. Per Acre	1931 % Lost	1932 Harvesting Method	1932 % Infested	1932 Yield in Lbs. Per Acre	1932 Loss in Lbs. Per Acre	1932 % Lost
Snow	Combined	14.0	1037	457	31	Combined	4.4	1400	152.5	9.8
Shrivers	"	5.7	1482	116	7	"	7.1	1680	82.8	4.7
Mater	"	2.2	1518	492	24	Mowed and threshed	5.6	1400	187.5	11.8
Kester	Mowed and threshed	7.4	1573	510	24	Mowed and threshed	8.2	1750	252.6	12.6
Olson	Combined	18.5	690	693	30	Mowed and threshed	3.3	1260	230.9	15.5
Bower	Combined	5.2	966	799	47	Combined	6.8	980	252.6	20.5
Pitzen	"	60.0	1656	404	20	"	6.7	2100	90.2	4.1
Hagedorn	"	0.6	1395	388	22	"	9.9	1880	121.9	6.1
Gibbs	Mowed and threshed	58.8	1375	442	24	Mowed and threshed	29.5	1680	278.8	14.2
Averages		18.0	1298	477	28	Averages	9.1	1570	183.3	11.0

The significance of harvest loss to weevil infestation is shown by a study of column 10 of Tables 24, 25 and 26, for in this column has been computed the number of weevil-infested peas left per acre on each of the fields examined. A theoretical loss of 1,450,176 weevil-infested peas was figured for one badly infested field in which the loss was extremely heavy. A heavy hibernating weevil population could rapidly develop from losses of this type. Plate 18 shows a typical bit of harvest loss.

It was apparent during the study on harvest loss that all the weevils in the shattered weevil-infested peas did not complete their development and emerge. The mortality was either due to the heat of the sun or to some phase of the harvesting process. In order to test this point two samples of peas, one shelled and the other in pods, were spread out on the ground at weekly intervals from the time the pods first ripened to the time when adult emergence started. A sample of peas from each lot was split to determine the stage to which the insects had developed at the time they were exposed. The results of the experiment are presented in Tables 28 and 29. The greatest mortality occurred among those weevils in shelled peas that were spread on the ground early in the season. No weevils emerged from peas that were spread in a shelled condition on July 29 and only 2.4 per cent were still living, while 29.6 per cent of the weevils in shelled peas emerged from those spread on September 16 and 28.4 per cent were still alive. Weevils in peas in pods fared better, for 4.4 per cent emerged from peas spread on July 29 and 20.8 per cent were still alive, while 66.8 per cent of those spread on September 16 emerged and 25.6 per cent were still alive when the peas were examined.

Table 28

Mortality Among Pea Weevils in Shelled Peas Spread Out on the Ground, Moscow, Idaho, 1933

Date Spread	Max. Temp. for week **	Results of Examination*					Stage of Development When Spread*				Per Cent *** Dead
		Dead Larvae	Dead Pupae	Dead Adults	Number Living	Number Emerged	Larvae	Pupae	Adults	Emerged	
July 29, '33	45.5° C.	80.0	16.4	1.2	2.4	0.0	100.0	0.0	0.0		
Aug. 5	54.0° C.	75.6	19.2	0.8	3.6	0.8	100.0	0.0	0.0		
Aug. 12	65.0° C.	54.0	28.0	6.4	9.6	2.0	98.8	1.2	0.0		3.1
Aug. 19	56.5° C.	10.4	40.0	13.6	22.8	13.2	75.6	24.4	0.0		10.7
Aug. 26	54.5° C.	15.6	31.2	11.6	20.8	20.8	43.6	54.4	2.00		6.6
Sept. 2	52.5° C.	8.0	37.2	14.8	14.8	29.2	31.2	49.2	19.6	0.0	7.6
Sept. 9	46.0° C.	11.6	28.0	10.8	27.2	22.4	14.0	34.0	32.8	19.2	8.0
Sept. 16	40.5° C.	6.0	22.4	13.6	28.4	29.6	12.8	30.8	48.4	8.0	9.4

* Figures in per cent. 250 individuals examined for each observation.
** Temperature in degrees Centigrade. Recorded by chemical mercury thermometer placed on the surface of the ground. Read at 1:00 P. M. daily.
***Number found dead in getting 250 weevils.

Table 29

Mortality Among Weevils in Peas in Pods Spread Out on the Ground at Weekly Intervals
Moscow, Idaho, 1933

Date Spread	Max. Temp. for week **	Results of Examination* Dead Larvae	Dead Pupae	Dead Adults	Number Living	Number Emerged	Stage of Development When Spread* Larvae	Pupae	Adults	Emerged	Per Cent *** Dead
July 29, '33	45.5° C.	71.2	3.2	0.4	20.8	4.4	100.0	0.0	0.0		
Aug. 5	54.0° C.	56.8	3.6	1.2	32.0	6.4	100.0	0.0	0.0		
Aug. 12	65.0° C.	34.0	8.0	1.6	31.2	25.2	98.8	1.2	0.0		3.1
Aug. 19	56.5° C.	6.0	2.0	1.6	6.0	64.4	75.6	24.4	0.0		10.7
Aug. 26	54.5° C.	9.6	0.4	0.8	22.8	66.4	43.6	54.4	2.0		6.6
Sept. 2	52.5° C.	7.6	2.8	2.4	26.4	60.8	31.2	49.2	19.6	0.0	7.6
Sept. 9	46.0° C.	10.4	2.0	1.2	32.0	54.4	14.0	54.0	32.8	19.2	8.0
Sept. 16	40.5° C.	8.0	1.2	0.4	23.6	66.8	12.8	30.8	48.4	8.0	9.4

* Figures in per cent. 250 individuals examined for each observation.
** Temperature in degrees Centigrade. Recorded by chemical thermometer placed on the surface of the ground. Read at 1:00 P. M. daily.
***Number found dead in getting 250 weevils.

A study of these figures shows that the harvest shatter may be of serious consequence, the degree depending on the time of harvest, and the stage to which the weevils have developed.

Volunteer peas. The shattered peas often pass the winter in the vicinity of Moscow, Idaho, without sprouting and come up the following spring as volunteer peas in the winter wheat. These volunteer peas during some years develop into producing vines and, as Wakeland (1933) has pointed out, produce a crop of weevil-infested peas. Large numbers of the insects complete their development in these peas and serve as an important source of adults that infest the next season's crop. A comparison of Plate 14 with Plates 15, 16 and 17 shows that many more weevils complete their development early and escape to hibernate from volunteer peas than from regular plantings. A study of 12 of these volunteer patches during 1932 showed an average weevil infestation of 71 per cent.

Volunteer peas are not always a menace, however, for occasionally after severe winters volunteer peas fail to grow, as they did after the winter of 1932-33.

Planting weevil-infested peas. Many farmers, in order to reduce the cost of production, sow weevil-infested peas, thinking that the adult weevils will be killed by burying. This is not the case, however, for large numbers of weevils emerge from peas buried at a depth of 3.5 inches, the average planting depth. The number of weevils that emerged depended on the condition of the soil when the peas were buried.

The data for this experiment were obtained by planting peas in rows 3.5 inches deep and then collecting the weevils as they emerged in a screen covered cage placed over the planted peas. The collections were made at approximately 4:00 o'clock in the afternoon and the soil temperature was recorded at that time.

One thousand peas were buried on April 18, which was the earliest possible planting date during 1932; another planting of 1500 peas was made on April 26 when field planting was starting, and a final series of 1500 was seeded on May 9. In the first series, 10.7 per cent of the weevils emerged, 34.7 per cent of those buried in the second series escaped, and 62.7 per cent of those planted May 9 came to the surface. A summary of the results is presented in Table 30.

Table 30

Emergence of Weevils from Planted Peas, Moscow, Idaho, 1932

Time of Emergence	Average Soil Temperature at $3\frac{1}{2}$ Inches	Emerged	Check
April 18 to May 24	59.9° F.	107	859
April 26 to May 30	63.3° F.	517	1282
May 9 to May 30	64.7° F.	941	1342

Experiments on Control

Methods

Small round cages eight inches in diameter and 15 inches deep were used to study the emergence of the weevil from buried weevil-infested peas. The cages were covered with wire screen having 16 meshes to the inch and were fitted with a friction top (Plate 19). In the field experiments, large cages five feet high and six feet square were used to collect and retain the weevils as they emerged.

Actual farm equipment was used in all field experiments. Care was also taken to plant all the experimental plots and to conduct all those involving the burying of weevil-infested material on ground devoted to pea growing. When possible, the experimental plots were arranged in quadruplicate according to the "randomized block" plan of plot arrangement (Paterson, 1933).

The burning equipment used in the Border Trap Crop Experiment was constructed for this experiment by Mr. O. K. Hedden of the Bureau of Agricultural Engineering coöperating with the Department of Agricultural Engineering of the University of Idaho. A detailed report, unpublished as yet, is on file in the office of the Division of Mechanical Equipment, Bureau of Agricultural Engineering.

Results

Methods for preventing the emergence of weevils in shattered peas. The most important source from which the weevil population arises each year, as has already been pointed out, is from shattered weevil-infested peas. It is quite evident that if this source of infestation could be eliminated the pea weevil problem would be materially lessened. Decidedly, the most economical method would be the elimination of shatter, but climatic factors such as wind, hail and rain, and wholesale harvesting methods make the accomplishment of this end seem hopeless. Much has been accomplished along this line already, but harvest loss cannot be eliminated entirely. Growing conditions are such in the Willamette Valley in Oregon that the weevils in shattered peas can be destroyed by burning the straw on the field after harvest (Larson, 1931).

Pea vines in the Palouse Area do not produce sufficient straw to carry a continuous fire across the harvested fields, so burning is of no value in this territory. Experiments were conducted during the fall of 1932 and 1933 to determine if burying the weevils by plowing or disking would kill the weevils.

Cage experiments with buried weevil-infested peas. The first of these experiments was devoted to determining the depth from which weevils buried in peas would emerge. Small round cages eight inches in diameter and about 15 inches in depth, made of fine screen wire having 16 meshes to the inch, were buried 10 inches in the ground. The bottom of the cages was filled with soil to within the desired distance of the ground level and then the weevil-infested peas were put in and the cages filled to the ground level with dirt. The emergence of the weevils was observed on 400 grams of weevil-infested peas buried at 0, 2, 4, 6, and 8 inches. The results of this study are summarized in Table 31. Plate 19 shows a view of the types of cage used in the experiment.

Table 31

Emergence of Weevils from Buried Peas*
Moscow, Idaho, 1931

Depth Buried	Series 1** Weevils Emerged		Series 2*** Weevils Emerged		Series 3**** Weevils Emerged	
	Number	Per Cent	Number	Per Cent	Number	Per Cent
Top	311	100	250	100	1178	100
2 inches	50	16.0	42	16.8	699	59.3
4 inches	10	3.2	33	13.2	33	2.7
6 inches	3	0.9	21	8.0	32	2.7
8 inches	3	0.9	3	1.2	42	3.7

* 400 grams of weevil-infested peas were buried at each depth in each series, but they were not from the same sample.
** Started August 19, 1931.
*** Started September 3, 1931.
****Started September 8, 1931.

A similar test was conducted during 1932 to determine the influence of the stage of the development of the weevil on their emergence from shattered peas. Five hundred ripe peas were buried to a depth of 3.5 inches from the time the peas were ripe until emergence of the weevils was in progress. Fifty pods were also buried at the same depth and a similar number of each was placed on top of the ground as a check. Very few of the weevils in the buried peas reached the surface and there was practically no difference in the number that emerged on the different dates, as shown in Table 32.

Table 32

Emergence of Pea Weevils from Peas Buried $3\frac{1}{2}$ Inches Deep at Weekly Intervals, Moscow, Idaho, 1932

Date Buried	Number Emerged			
	Loose Peas*		Pods**	
	Buried	Check	Buried	Check
August 6, 1932	2	354	0	201
August 13 "	1	234	1	178
August 20 "	0	224	1	140
August 27 "	2	216	0	98
September 5, 1932	1	230	0	108
September 10,1932	1	243	0	122

* 500 shelled peas were buried and 500 additional peas placed on top of the ground as a check.

**50 pods were buried and 50 additional pods were placed on top of the ground as a check.

Field experiments with buried weevil-infested peas. Small cage experiments showed such favorable results that an experiment was planned to test the effect of burying on a larger scale with the aid of farm machinery. It was apparent that the weevils were covered with a more finely pulverized soil in the cage experiments than they would be if buried by a plow or disk. Three plots of ground six feet square were staked out on a pea field from which the peas had been just recently harvested. Fifteen thousand weevil-infested peas were spread out on each of the plots. Then one of these was plowed under to a depth of about eight inches with a caterpillar tractor and a four-gang plow, the second was disked under, and the third was left as a check. Two similar plots of uncut vines were staked off; one of these was plowed under and the other was left as a check. Each of these plots was covered by a large screen cage made of sixteen-mesh wire to retain the weevils as they emerged. The results of this field experiment agreed very well with the small cage experiments, for 69.07 per cent of the weevils left on top of the ground as a check emerged, while only 2.63 per cent of the weevils in the peas that were plowed under were able to emerge. Plowing was much more effective than disking, as shown by Table 33.

Table 33

The Influence of Plowing and Disking on the Number of Weevils Emerging from Unharvested Peas, Moscow, Idaho, 1932.

Treated	Number Treated Peas	Number Emerged	Per Cent Emerged
Placed on top of ground as a check	15,000	9146	69.07
Disked under with a two-way disk	15,000	2073	13.82
Plowed under with a four-gang plow	15,000	395	2.63
No treatment	6 sq. ft. of vines	1152	100.00
Plowed under with a four-gang plow	6 sq. ft. of vines	127	11.02

<u>Time of planting as a method of weevil control.</u> Every farmer knows that the time of sowing has something to do with the amount of weevil damage his peas suffer. Early seeding in weevil-infested territory is usually accompanied by heavy loss from weevils. During 1933 and 1934 plantings were made at weekly intervals to determine whether early planted peas actually had a heavier amount of weevil infestation and if a planting date could be found where one could seed and feel confident that his peas would be weevil-free.

Plantings were made for 11 consecutive weeks from April 6, 1933, to June 15. Each planting consisted of five rows 60 feet long and three feet apart. The weevil infestation data were computed from a sample picked at random through the plantings. The yield data were obtained from 25 vines picked at random. The peas were counted to obtain the yield information to eliminate the error caused by the difference in weight between weevil-infested and sound peas.

The highest infestation, 59.6 per cent, occurred on the eighth planting, which was seeded on the 25th of May. The first planting had an infestation of 14.4 per cent and had next to the lowest amount of weevil damage. The first planting also produced the most peas on 25 vines. These interesting data are presented in Table 34.

The study was repeated again in 1934 with the plantings executed in quadruplicate. Thirteen plantings were made from February 19 to July 2. The seedings consisted of five rows 58 feet long planted two feet apart. Each sowing was made on the date when the preceding planting started coming up or as soon after that date as possible. Plates 20 and 21 show the arrangement of the plots.

The results for 1934 differed materially from those of 1933, as shown by Tables 35 and 36. The greatest weevil damage, 54.7 per cent, occurred on planting 2, which was seeded on March 14, and the greatest yield occurred on planting 3, which was planted on April 6. The smallest amount of weevil damage occurred on the last seedings that produced peas in both seasons, but the yield in both cases was very poor and the peas produced were unfit for market purposes. The minimum infestation during 1933 was

Table 34

Relation of Time of Planting to the Amount of Weevil Damage at Moscow, Idaho, 1933

Planting Number	Planted	First Bloom	First Weevil Egg	Total Number of Eggs on 25 Vines	Total Number of Peas on 25 Vines	Per Cent Infested
1	April 6	June 3	June 12	171	1272	14.4
2	" 13	" 5	" 15	88	1025	15.0
3	" 20	" 6	" 15	364	764	23.2
4	" 27	" 10	" 17	195	955	37.2
5	May 4	" 15	" 21	268	762	29.4
6	" 11	" 17	" 25	685	942	30.4
7	" 18	" 22	" 27	662	721	39.8
8	" 25	" 26	July 5	591	681	59.6
9	June 1	July 3	" 9	300	596	44.2
10	" 8	" 8	" 15	90	669	15.8
11	" 15	" 15	" 21	38	260	4.4

Table 35

Relation of the Time of Planting to the Amount of Weevil Damage, Moscow, Idaho, 1934

Date Planted	Per Cent Infested				
	Series A	Series B	Series C	Series D	Average
February 19	52.2	Unplanted because of wet ground.			52.2
March 14	59.0	51.4	42.2	66.2	54.7
April 6	61.4	44.4	38.8	72.0	54.1
April 16	42.8	53.4	40.2	46.9	45.8
April 24	44.2	31.2	31.2	34.1	35.2
May 2	35.4	36.6	24.0	5.5	20.4
May 10	21.0	17.4	14.6	7.5	15.1
May 17	—[5]	—[5]	7.6	3.6	5.6
May 29	6.8	16.2	14.2	4.8	8.4
June 5	22.0	5.2	15.0	3.6	11.4
June 12	17.4	4.8	1.2	—[4]	7.8
June 19	5.1	—[4]	—[4]	—[5]	5.1
July 2	—[4]	—[4]	—[4]	—[5]	

[1]Planting D seeded, March 22, 1934.
[2] " " " April 5, 1934.
[3] " " " April 17, 1934.
[4]Failed to produce peas.
[5]Unplanted.

Table 36

Relation of the Time of Planting to the Amount of Weevil Damage, Moscow, Idaho, 1934

Planted	First Bloom*	Last Bloom*	Series A No. of Peas	Series A Wt. in G.	Series B No. of Peas	Series B Wt. in G.
February 19	April 27	May 29	2422	547		
March 14	May 5	May 31	3346	710	4722	934
April 6	May 19	June 27	7637	1396	7216	1392
April 16	May 26	July 2	2980	487	5063	867
April 24	May 31	July 9	5358	929	3471	641
May 2	June 6	July 16	4698	777	5040	788
May 10	June 12	July 17	2659	357	5698	818
May 17[4]	———	———	——	——	——	——
May 29	June 28	July 20	1335	147	1416	151
June 5	July 9	July 24	637	715	——[1]	
June 12	July 16	July 26	——[2]			
June 19	July 20	July 30	——[3]			

* These dates were the same for Series A and B.

1 2 3 Peas small and shriveled and of no use commercially, so no weights or counts were made.

4 This planting was destroyed by laborer.

4.4 per cent and for 1934 it was 5.1 per cent.

Use of insecticides in the control of the pea weevil. Laboratory experiments. Four insecticides, calcium arsenate, barium fluosilicate, pyrethrum, and derris, were used in these tests. Each insecticide was tested in four different ways. First, blossoms taken from field dusted plots were given as food to untreated weevils; second, hand dusted blossoms were given as food to untreated weevils; third, laboratory dusted weevils were placed on undusted blooms; and, finally, weevils forced to walk two inches over a dusted surface were placed on fresh blossoms.

The weevils were placed in vials 7/8 inch in diameter and 3 3/4 inches long, as shown in Plate 22. Fresh untreated blossoms were added daily to each vial in each of the experiments. One hundred weevils were treated, in most cases, in each experiment. The weevils used in the experiments were collected from the field until it became apparent that natural mortality was responsible for a portion of the deaths that occurred. Weevils from a laboratory supply then were used.

Niagara calcium arsenate was used undiluted in these tests. Barium fluosilicate prepared by the Grasselli Chemical Company and sold as Dutox was used as prepared. A 1 per cent dust of Rotenone (S. B. Penick & Company, New York) was prepared from powdered derris root containing 5 per cent Rotenone. Diatomaceous earth was used as the diluting medium. The pyrethrum dust was made up as a 50-50 mixture of powdered pyrethrum flowers containing 0.9 per cent of total pyrethrins and diatomaceous earth. The powdered pyrethrum flowers were prepared by McCormick & Co., Baltimore, Maryland.

Experiments with field dusted blossoms. Plots 1/40 acre in extent were staked off and dusted with a Root hand duster at the rate of 20 pounds per acre. The blossoms to be used in the experiment were picked at random from the dusted plots. Care was used in handling the blossoms to prevent the loss of the dust.

Freshly dusted blossoms from previously undusted plots were given to the weevils daily in the experiments with calcium arsenate and barium fluosilicate. One series of experiments was started with both derris and pyrethrum immediately after dusting and a second series with both was started 24 hours later to test the duration of the effectiveness of the dusts. The results are presented in Table 37.

Table 37

Results of Laboratory Tests with Blossoms from Field Dusted Plots on the Pea Weevil.

		Results (Accumulating Percentages)				
Date	Treatment	Living	Paralyzed	Dead	Escaped	No. Tested
Results with calcium arsenate						
June 19, 1934	Started	100.0				
20	Fresh dusted blossoms added	76.8	11.2	9.2	2.8	
21	" "	6.8	15.2	52.8	3.2	250
22	Fresh undusted	7.2	8.8	80.8	3.2	
23	blossoms added	0.4	4.8	91.6	3.2	
25	" "	0.4	0.0	96.4	3.2	
Results with barium fluosilicate						
June 20, 1934	Started	100.0				
21	Fresh dusted	65.2	9.2	24.8	0.8	
22	blossoms added	20.8	9.6	68.8	0.8	250
23	Fresh undusted	10.0	4.0	85.2	0.8	
24	blossoms added	4.0	2.4	92.8	0.8	
25	" "	2.0	0.8	96.4	0.8	
26	Exp. terminated	2.0	0.0	97.2	0.8	

Table 37 (Cont.)

Date	Treatment	Results (Accumulating Percentages) Living	Paralyzed	Dead	Escaped	No. Tested
Check - No treatment - Weevils unfed						
June 21, 1934	Placed in vials without food	100.0		0.0		
22	No food	100.0		0.0		
23	" "	96.0		4.0		
24	" "	79.0		21.0		
25	" "	52.0		48.0		100
26	" "	39.0		61.0		
27	" "	34.0		66.0		
28	" "	30.0		70.0		
29	" "	23.0		77.0		
30	" "	21.0		79.0		
July 1	Exp. terminated	19.0		81.0		
Results with Rotenone (Powdered derris root)						
June 27, 1934	Started	100.0				
28	Fresh undusted	2.4	92.0[1]	2.0	3.6	
29	blossoms added	6.8	64.0	27.6	3.6	
30	" (Released)	2.0	25.2	69.2	3.6	250
July 1	" "	2.4	4.4	89.6	3.6	
2	" "	2.4	1.2	92.8	3.6	
3	" "	2.4	0.0	94.0	3.6	
Check for Rotenone - Weevils Unfed						
June 27, 1934	Started, weevils	100.0		0.0		
28	placed in vials	100.0		0.0		
29	without food	100.0		0.0		50
30	" "	28.0		72.0		
July 1	" "	2.0		98.0		
2	" "	2.0		98.0		
3	" "	0.0		100.0		
Results with Pyrethrum						
July 5, 1934	Started	100.0				
6	Fresh undusted	32.0	45.2	20.8	2.0	
7	blossoms added	22.4	22.8	52.8	2.0	250
8	" "	11.6	4.8	81.6	2.0	
9	" (Released)	3.6	0.0	94.4	2.0	

Table 37 (Cont.)

Date	Treatment	Results (Accumulating Percentages) Living	Paralyzed	Dead	Escaped	No. Tested
Check - Weevils unfed						
July 5	Started. Weevils	100.0				
6	placed in vials	96.0		4.0		
7	without food	50.0		50.0		50
8	" "	10.0		90.0		
9	" "	0.0		100.0		

[1]Most of these weevils were quite active for a very short time after being disturbed and several even could fly a short distance, but they were all unable to walk. In the vials they laid on their backs and turned somersaults.

Experiments with hand dusted blossoms. This experiment was conducted to see if a more thorough coverage with each of the dusts would increase the effectiveness. The blossoms were passed directly through the dust blast from a Savage duster set and turned at the rate that experience had shown to be necessary to deliver 20 pounds of the dusts per acre. The blossoms were placed in individual shell vials and weevils taken from field collections were added. The results are incorporated in Table 38. Although the duster was set to deliver 20 pounds of dust per acre, undoubtedly more dust was applied per blossom than would ordinarily cover one bloom during actual field dusting operations.

Table 38

Results of Laboratory Tests with Hand Dusted Blossoms on the Mortality of the Pea Weevil.

Date	Treatment		Results (Accumulating Percentages) Living	Paralyzed	Dead	Escaped	No. Tested
Results with Calcium Arsenate[1]							
July 10, 1934	Started		100.0				
11	Fresh undusted		74.0	16.0	0.0	10.0	
12	blossoms added		68.0	20.0	2.0	10.0	
13	added (Released)		48.0	8.0	14.0	10.0	
14	"	"	48.0	18.0	24.0	10.0	50
15	"	"	48.0	14.0	28.0	10.0	
16	"	"	48.0	12.0	30.0	10.0	
17	"	"	48.0	4.0	38.0	10.0	
18	"	"	52.0	0.0	38.0	10.0	
Results with Barium Fluosilicate[1]							
July 12, 1934	Started		100.0				
13	Fresh undusted		86.0	6.0	2.0	6.0	
14	blossoms added		75.0	8.0	11.0	6.0	
15	"	"	60.0	8.0	26.0	6.0	100
16	"	"	57.0	5.0	32.0	6.0	
17	"	"	57.0	2.0	35.0	6.0	
18	"	"	55.0	1.0	38.0	6.0	
19	"	"	50.0	4.0	40.0	6.0	
20	"	"	50.0	1.0	43.0	6.0	
Check - Weevils Fed Fresh Blossoms Daily[1]							
July 10, 1934	Started		100.0				
11	Fresh blossoms		100.0		0.0		
12	added		100.0		0.0		
13	"	"	100.0		0.0		
14	"	"	94.0		4.0	2.0	50
15	"	"	92.0		4.0	4.0	
16	"	"	92.0		4.0	4.0	
17	"	"	88.0		6.0	6.0	
18	"	"	88.0		6.0	6.0	
19	"	"	88.0		6.0	6.0	
20	"	"	86.0		8.0	6.0	
Results with Rotenone							
June 27, 1934	Started		100.0				
28	Fresh undusted		0.0	77.0	23.0	0.0	
29	blossoms added		0.0	26.0	74.0		100
30	"	"	0.0	2.0	98.0		
July 1	"	"	0.0	0.0	100.0		

Table 38 (Cont.)

Date	Treatment	Results (Accumulating Percentages) Living	Paralyzed	Dead	Escaped	No. Tested
Results with Pyrethrum						
July 3, 1934	Started	100.0				
4	Fed fresh	0.0	71.0	28.0	1.0	
5	blossoms	1.0	8.0	90.0	1.0	100
6	"	1.0	1.0	97.0	1.0	
7	"	0.0	0.0	99.0	1.0	

[1]Weevils taken directly from the laboratory supply were used in these tests because the field supply was dwindling rapidly and the weevils appeared to be less resistant.

The results of these experiments show that one application of calcium arsenate or barium fluosilicate, even though thoroughly applied, will not kill all the weevils if they are exposed for only 24 hours. A thorough coverage of derris and pyrethrum dusts killed all the weevils in these tests.

Experiments with hand dusted weevils. The weevils used in these tests were placed in cages 8 inches x 14 inches made of sixteen-mesh screen. The cage was started rolling over the ground and as it rolled it was dusted with the machine set and cranked to deliver 20 pounds of dust per acre. Immediately after the dusting was completed the weevils were placed in shell vials on undusted blooms. This treatment completely covered the weevils with dust. A study of Table 39, which presents the results of this experiment, shows clearly that dusting weevils with calcium arsenate and barium fluosilicate will not kill all the weevils, whereas pyrethrum and Rotenone applied as dusts are very effective.

Table 39

Results of Laboratory Tests with Hand Dusted Pea Weevils Placed on Fresh Blossoms.

Date	Treatment	Results (Accumulating Percentages)				
		Living	Paralyzed	Dead	Escaped	No. Tested
Results with Calcium Arsenate[1]						
July 10, 1934	Started	100.0				
11	Fresh undusted	72.0	28.0			
12	blossoms added	76.0	20.0	4.0		
13	" "	66.0	20.0	14.0		50
14	" "	70.0	12.0	18.0		
15	" "	66.0	8.0	26.0		
16	" "	66.0	4.0	30.0		
17	" "	66.0	2.0	32.0		
18	" "	66.0	0.0	34.0		
Calcium Arsenate - Second Test[1]						
July 12, 1934	Started	100.0				
13	Fresh undusted	86.0	14.0	0.0		
14	blossoms added	68.0	22.0	10.0		
15	" "	60.0	4.0	36.0		
16	" "	56.0	6.0	38.0		50
17	" "	58.0	4.0	38.0		
18	" "	54.0	6.0	40.0		
19	" "	54.0	0.0	46.0		
20	" "	54.0	0.0	46.0		
21	" "	52.0	2.0	46.0		
Results with Barium Fluosilicate[1]						
July 12, 1934	Started	100.0				
13	Fresh blossoms	96.0	2.0	1.0	1.0	
14	added	83.0	8.0	7.0	2.0	
15	"	69.0	17.0	12.0	2.0	100
16	"	65.0	11.0	22.0	2.0	
17	"	64.0	3.0	31.0	2.0	
18	"	64.0	3.0	31.0	2.0	
19	"	64.0	0.0	34.0	2.0	

Table 39 (Cont.)

Date	Treatment	Results (Accumulating Percentages) Living	Paralyzed	Dead	Escaped	No. Tested
Check - Weevils Fed Undusted Blossoms						
July 10, 1934	Started	100.0				
11	Fresh blossoms	100.0		0.0		
12	added	100.0		0.0		
13	"	100.0		0.0		
14	"	94.0		4.0	2.0	
15	"	92.0		4.0	4.0	50
16	"	92.0		4.0	4.0	
17	"	88.0		6.0	6.0	
18	"	88.0		6.0	6.0	
19	"	88.0		6.0	6.0	
20	"	86.0		8.0	6.0	
Results with Rotenone						
June 27, 1934	Started	100.0				
28	Fresh blossoms	4.0	61.0	33.0	2.0	
29	" "	2.0	6.0	90.0	2.0	100
30	" "	1.0	0.0	97.0	2.0	
Results with Pyrethrum						
July 3, 1934	Started	100.0				
4	Fresh blossoms	3.0	44.0	53.0		100
5	added	3.0	3.0	94.0		
6	"	3.0	0.0	97.0		

[1]Weevils taken from sacks stored in the laboratory.

The effect of walking through insecticides on the mortality of the pea weevil. The pea weevil does little actual feeding on the pea vine and practically no feeding in places that can be readily covered with a poison dust. A large portion of the poison falls on the foliage where the only way in which it could come in contact with the insect would be through its appendages. Pea weevils spend much time cleaning their tarsi, for any dust on their feet makes it difficult for them to adhere to the smooth foliage of the pea plant. Poison dust, in sufficient quantities to cause death, might be taken into the insect in this manner. Table 40 presents the results of a study designed to determine if enough poison to cause death would be taken up in this way in a short trip over a dusted surface.

The weevils were treated by forcing them to walk through a ring of dust on a pane of glass. A hole 1/4 inch in diameter was bored in a pane of glass. The cleaned glass was placed on a smooth surface and dusted with the dust gun set at the position experience had shown would deliver 20 pounds per acre. All the dust was wiped off with the exception of a disk of dust four inches in diameter with the 1/4 inch hole at the center. A second pane of glass was suspended 3/16 inch above the dust disk by bits of plastic clay placed at each of its corners. This whole apparatus was placed over a cup containing the desired number of weevils. The weevils were retained in the cup by a slide which was perforated with a 1/4 inch hole. When the hole in the slide and the dust-covered pane of glass were made to coincide, the caged weevils which have a positive phototropic reaction could escape. The pane of glass suspended above the hole kept the weevils from flying and forced them to walk through two inches of dust. Each insect that walked this distance through the dusts had each of its tarsi covered with a ball of dust. Some of the insects were able to turn over and walk upon the upper pane of glass, but these were discarded.

A study of Table 40 shows that only a few insects are able to pick up enough calcium arsenate or barium fluosilicate to kill them by walking this distance. This is true in spite of the fact that the tarsi of every weevil were covered with the poisons. Enough Rotenone and pyrethrum were picked up to kill many of the weevils, but not enough to insure complete mortality.

Table 40

Effect of Walking Through Insecticides on the Mortality of the Pea Weevil.

Date	Treatment	Results (Accumulating Percentages				
		Living	Paralysed	Dead	Escaped	No. Tested
Results with Dutox (Weevils Collected from Field)						
June 22, 1934	Started	100.0				
23	Fresh blossoms	98.0	0.0	2.0		100
24	added	93.0	0.0	7.0		
25	" "	30.0	0.0	69.0	1.0	
Check - No Food Added (Weevils Collected from Field)						
June 21, 1934	Started	100.0				
22	No food added	100.0		0.0		
23	" "	96.0		4.0		100
24	" "	79.0		21.0		
25	" "	47.0		53.0		
Results with Calcium Arsenate (Weevils from Laboratory Supply)						
July 10, 1934	Started	100.0				
11	Fresh blossoms	99.0		1.0		
12	added	99.0		1.0		
13	" "	99.0		1.0		100
14	" "	99.0		1.0		
15	" "	98.0	1.0	1.0		
16	" "	98.0	0.0	2.0		
Results with Rotenone (Weevils Collected from Field)						
June 29, 1934	Started	100.0				
30	Fresh blossoms	16.0	77.0	6.0	1.0	
July 1	" "	22.0	35.0	42.0	1.0	100
2	" "	22.0	5.0	72.0	1.0	
3	" "	22.0	0.0	77.0	1.0	
Check - Unfed (Weevils Collected from the Field)						
June 27, 1934	Started	100.0				
28	No food added	100.0				
29	No examinations					
30		28.0		72.0		50
July 1		2.0		98.0		
2		2.0		98.0		
3		0.0		100.0		

Table 40 (Cont.)

Date	Treatment	Results (Accumulating Percentages) Living	Paralyzed	Dead	Escaped	No. Tested
Results with Pyrethrum (Weevils Collected from the Field)						
July 5, 1934	Started	100.0				
6	Fresh blossoms added	33.0	37.0	30.0		
7	" " "	16.0	15.0	68.0	1.0	100
8	" " "	7.0	2.0	90.0	1.0	
9	" " "	3.0	3.0	93.0	1.0	
Check - Unfed (Weevils Collected from the Field)						
July 5, 1934	Started	100.0				
6	No food added	96.0		4.4		
7	" " "	50.0		50.0		50
8	" " "	10.0		90.0		
9	" " "	0.0		100.0		

Field tests with insecticides. Field tests were conducted with several insecticides on the pea weevil, for it was felt that an active insect, such as this, might be much more susceptible to insecticides in small cages than under field conditions. Four different experiments were started: the first to compare the effectiveness of calcium arsenate, barium fluosilicate, zinc arsenite, sodium fluoaluminate, lead arsenate, and lime; the second to test the effectiveness of a number of applications of calcium arsenate; the third to determine the influence of varied dosages of calcium arsenate; and the last to test the effectiveness of two different brands of calcium arsenate, one of which contained an adhesive agent.

Procedure and technique. The plots in this experiment were executed in quadruplicate and arranged by chance according to the "randomized block" method of plot arrangement (Paterson, 1933). The arrangement of the blocks and the position of the plots within the blocks are shown in Plate 21. Each of the plots was 1/40 of an acre in extent and measured 66 feet in length and 16.5 feet in width. The plots were placed with their narrow end to the edge of the field to expose the maximum number of plots to the heavy weevil infestation that usually occurs along the edge of a pea field. It was necessary, because of continued wet weather which prevented seeding, to arrange the plots in Block I in the form of an "L."

The location used was selected because it was typical of the topography of the country and would provide plots situated at different elevations. This location was also favorable because it was located in a badly infested territory.

Regular field practices were followed in seeding the plots except that the peas were planted earlier than it was advisable to start commercial plantings. This was done in order that the plots might become very heavily infested and so that there would be very few other peas in bloom in the same locality when the plots started to blossom. A twenty-two foot border was planted between the plots and a late planting of peas to prevent an infestation of this crop through migration.

The plots were dusted with hand dusters. Five trips the length of the plots usually sufficed to cover the area and put on the desired amount of dust. The dust guns were weighed before and after each application. If more than the desired amount had been applied, it was recorded; but if less than the amount had been put on, an additional trip was made through the plot. Continued use of the guns enabled one to become proficient in applying approximately the correct quantity of dust. The amount of dust applied and the dates of application are presented in Table 41.

Table 41

Date Applied and Rate of Application of Insecticides in Plot Experiments

Insecticide	Block	Date Applied: May 19	May 21	May 24	May 28	May 31	June 2	June 7
Calcium	1	8 oz.						
arsenate°	2	8 oz.						
One	3	8 "						
application	4	8 "						
Calcium	1	8 "	10 oz.					
arsenate°	2	8 "	8 "					
Two	3	8 "	9 "					
applications	4	8 "	8 "					
Calcium	1	8 "	10 "	8 oz.	8 oz.			
arsenate	2	8 "	8 "	8 "	8 "			
Four	3	8 "	8 "	8 "	8 "			
applications	4	8 "	8 "	8 "	10 "			
Calcium	1							
arsenate°	2	8 "	10 "	7 "	9 "	8 oz.	8 oz.	
Six	3	8 "	7 "	10 "	8 "	8 "	8 "	
applications	4	8 "	8 "	8 "	9 "	8 "	8 "	
Calcium	1	8 "	7 "	8 "	8 "	8 "	10 "	8 oz.
arsenate°	2	16 "	9 "	9 "	10 "	8 "	11 "	8 "
Seven	3	8 "	11 "	10 "	9 "	8 "	8 "	8 "
applications	4	8 "	8 "	10 "	8 "	8 "	8 "	8 "
Calcium	1	8 "	8 "		8 "	8 "	8 "	8 "
arsenate[1]	2	8 "	8 "		8 "	8 "	8 "	8 "
Five lbs.	3	8 "	8 "		8 "	8 "	8 "	8 "
per acre	4	8 "	8 "		8 "	8 "	8 "	8 "
Calcium	1	10 "	8 "		8 "	8 "	8 "	8 "
arsenate[2]	2	8 "	8 "		8 "	8 "	8 "	8 "
Ten lbs.	3	10 "	8 "		11 "	8 "	8 "	8 "
per acre	4	8 "	8 "		11 "	8 "	11 "	10 "
Calcium	1	8 "	8 "		8 "	8 "	8 "	8 "
arsenate[3]	2	8 "	8 "		8 "	8 "	8 "	8 "
Fifteen lbs.	3	8 "	8 "		8 "	8 "	8 "	8 "
per acre	4	8 "	10 "		8 "	8 "	10 "	8 "
Calcium	1	8 "	8 "	8 oz.	12 "	8 "	8 "	8 "
arsenate[4]	2	8 "	10 "	8 "	8 "	8 "	8 "	8 "
Twenty lbs.	3	8 "	8 "	8 "	8 "	8 "	8 "	8 "
per acre	4	8 "	8 "	8 "	8 "	8 "	13 "	8 "
Calcium	1	16 "	16 "	16 "	16 "	16 "	16 "	16 "
arsenate[4]	2	16 "	19 "	16 "	16 "	16 "	16 "	16 "
Forty lbs.	3	16 "	16 "	16 "	16 "	16 "	16 "	16 "
per acre	4	16 "	16 "	16 "	16 "	16 "	16 "	16 "

Table 41 (Cont.)

Insecticide	Block	Date Applied May 19	May 21	May 24	May 28	May 31	June 2	June 7
Lead	1	8 oz.	8 oz.	8 oz.	8 oz.	8 oz.	8 oz.	
arsenate	2	8 "	8 "	8 "	8 "	8 "	6 "	
	3	8 "	9 "	8 "	10 "	8 "	8 "	
	4	8 "	8 "	8 "	8 "	8 "	6 "	
Sodium	1	8 "	8 "*		8 "	8 "	9 "	8 oz.
fluoaluminate	2	8 "	8 "		10 "	8 "	8 "	9 "
	3	10 "	8 "		8 "	8 "	8 "	9 "
	4	8 "	8 "		8 "	8 "	8 "	8 "
Barium	1	10 "	12 "		8 "	8 "	8 "	8 "
fluosilicate	2	10 "	15 "		8 "	8 "	8 "	8 "
	3	12 "	9 "		8 "	8 "	8 "	8 "
	4	8 "	8 "		8 "	8 "	8 "	8 "
Zinc	1	9 "	11 "		10 "	8 "	8 "	8 "
arsenite	2	8 "	8 "		8 "	8 "	8 "	8 "
	3	12 "	8 "		8 "	8 "	8 "	8 "
	4	8 "	9 "		8 "	8 "	8 "	8 "
	1	11 "	8 "		8 "	8 "	8 "	8 "
Lime	2	9 "	8 "		8 "	8 "	8 "	8 "
	3	8 "	8 "		8 "	8 "	8 "	8 "
	4	8 "	8 "		8 "	8 "	9 "	8 "

*May 22.
[o]Moca. Calcium Arsenate.
[1]25% calcium arsenate - 75% lime.
[2]50% calcium arsenate - 20% lime.
[3]75% calcium arsenate - 25% lime.
[4]100% calcium arsenate.

<u>Insecticides</u> <u>used</u>. A summary of the insecticides used and rates of application, is presented in Table 42. The calcium arsenate (Niagara) contained 70 per cent of active ingredients and 30 per cent inert material. This material was applied at the rate of 40, 20, 15, and 5 pounds per acre. In order to apply the quantities below the rate of 20 pounds per acre, the material had to be diluted. Hydrated lime was used as the diluting agent. Calcium arsenate sold by the California Spray-Chemical Corporation under the trade name of "Moca" contained 50 per cent active ingredients. This dust

contained dehydrated, powdered molasses as an adhesive agent. The barium fluosilicate used, purchased under the trade name of "Dutox," contained 80 per cent of active ingredients. This insecticide was applied without further dilution. Zinc arsenite, sodium fluoaluminate, and lead arsenate were purchased from the California Spray-Chemical Corporation and were applied without dilution.

Sampling method. Considerable thought was devoted to the sampling method to be used in the examination of these plots. The method finally adopted, one that seemed most likely to give the most accurate picture of the infestation, consisted of harvesting all the peas on a strip three feet wide and 12 feet long. One thousand peas were taken from the quantity thus secured and examined by salt flotation to determine the weevil content.

Infestation in the plots. No attempt was made to determine the actual infestation in the individual plots or to follow its development through its phases because of the disturbing influence such counts might have on the weevil population. A count was made, at what appeared to be peak of the infestation, by taking 50 sweeps with a fifteen-inch collecting net in the check plot at the west end of the south tier of plots. The infestation was so heavy that 662 weevils were collected. A cage covering 36 square feet of surface was placed over a section of peas, adjacent to the plots but not included in the plot layout, on May 23. The following day 249 weevils were collected in the cage.

Results. Sodium fluoaluminate gave the best control of all the combinations tried. The average infestation for the four plots of 6.1 per cent compared with an average infestation of 32.9 per cent in the undusted check plots. The summary of the results is presented in Table 42. Table 43 presents the results for the 64 plots in detail.

Table 42

Average Results of Insecticide Tests Arranged According to Their Effectiveness.

Insecticide	Number of Applications	Rate of Applications	Per Cent Sound*	Per Cent Weevily*
Sodium fluoaluminate	6	20 lbs. per acre	93.9	6.1
Zinc arsenite	6	20 " " "	93.2	6.8
Calcium arsenate***	6	20 " " "	93.0	7.0
Calcium arsenate***	4	20 " " "	91.9	8.1
Calcium arsenate***	2	20 " " "	91.6	8.4
Barium fluosilicate	6	20 " " "	90.3	9.7
Calcium arsenate**	7	40 " " "	90.0	10.0
Calcium arsenate**	7	20 " " "	89.7	10.3
Calcium arsenate***	7	20 " " "	89.4	10.6
Calcium arsenate	6	10 " " "	87.9	12.1
Lead arsenate	6	20 " " "	86.1	13.9
Calcium arsenate**	6	15 " " "	84.4	15.6
Calcium arsenate***	1	20 " " "	83.9	16.1
Calcium arsenate**	6	5 " " "	83.6	16.4
Lime	6	20 " " "	77.6	22.4
Check	No treatment		67.1	32.9

* Average of the results from four 1/40 acre plots. 1000 peas examined from each plot.
** Niagara calcium arsenate.
***Moca (California Spray-Chemical Corporation) calcium arsenate.

Table 43

Results of Insecticide Tests, Moscow, Idaho, 1934

Treatment	Block	Results: Per Cent Weevily	Results: Average Per Cent Weevily
Results with Varying Number of Applications of Calcium Arsenate (Moca)			
One application	1	22.0	
	2	19.5	
	3	18.4	
	4	4.5	16.1
Two applications	1	9.7	
	2	10.5	
	3	3.5	
	4	10.2	8.4
Four applications	1	10.4	
	2	3.9	
	3	3.2	
	4	14.9	8.1
Six applications	1		
	2	4.8	
	3	6.4	
	4	10.8	7.0
Seven applications	1	20.0	
	2	13.0	
	3	4.3	
	4	5.1	10.6
Results with Varied Quantities of Calcium Arsenate (Niagara)			
Five pounds per acre of calcium arsenate	1	23.8	
	2	12.6	
	3	24.6	
	4	4.5	16.4
Ten pounds per acre of calcium arsenate	1	19.1	
	2	15.0	
	3	7.1	
	4	7.5	12.1
Fifteen pounds per acre of calcium arsenate	1	17.1	
	2	9.0	
	3	2.6	
	4	33.6	15.6
Twenty pounds per acre of calcium arsenate	1	12.3	
	2	2.7	
	3	6.5	
	4	19.7	10.3

Table 43 (Cont.)

Treatment	Block	Results: Per Cent Weevily	Results: Average Per Cent Weevily
Results with Varied Quantities of Calcium Arsenate (Niagara), (Cont.)			
Forty pounds	1	22.6	
per acre of	2	4.8	
calcium arsenate	3	5.6	
	4	7.0	10.0
Results with Other Dusts			
Sodium	1	9.2	
fluoaluminate	2	5.1	
	3	2.8	
	4	7.2	6.1
Lead	1	26.5	
arsenate	2	4.8	
	3	17.4	
	4	7.1	13.9
Zinc	1	10.6	
arsenite	2	8.1	
	3	3.1	
	4	5.6	6.8
Barium	1	9.4	
fluosilicate	2	4.5	
	3	4.1	
	4	20.9	9.7
Check Plot Results			
Lime	1	37.0	
	2	25.0	
	3	3.2	
	4	24.6	22.4
No dust of	1	47.4	
any kind	2	13.4	
	3	10.3	
	4	22.5	32.9
	Extra	70.8	

Border trap crop as a method of pea weevil control. One of the first things apparent to one familiar with the habits of the pea weevil is the fact that the edges of the field, especially those adjacent to favorable hibernating quarters, are more heavily infested than sections remote from the edge. This border effect is so marked at times that the seriousness of the infestation can almost be said to vary directly with the distance from the edge of the field. Wakeland (1933) adequately pictured this feature of the infestation. Occasionally certain factors such as the presence of high hills, low places, and the presence of favorable hibernating quarters, within a field modify this general truth. Farmers, alert to the weevil problem, often hold out the bags of peas from the first combine round when their peas are graded because they have learned that they are the most heavily infested, which results in a high weevil dockage.

This information, in addition to the well-known fact that the weevils are usually attracted in large numbers to the earliest planted peas, suggested the idea that it might be possible to attract the weevils to a border trap crop of peas planted earlier than the main field. Once concentrated in the border it was thought that the weevils would either exhaust their egg supply on the trap crop or that some method such as plowing, burning, or poisoning the massed weevils could be devised to eliminate them.

Experimental procedure. Early in the springs of 1932, 1933 and 1934, borders of early planted peas were sown about the edge of several very badly infested fields. The borders planted were 11 feet wide during 1932 and 1933 and were increased to 22 feet during 1934. The main fields were then planted within the borders two or three weeks later at the time when soil and climatic conditions were at their best for pea seeding.

The development of the weevil population was followed by sweeping with a fifteen-inch insect collecting net at regular intervals about the border, next to the border, 50-100 feet in from the borders, and in the center of the fields. The blooming dates of the border plantings and of the main seeded fields were recorded. This information was desired to note any movements of the weevils that might be caused by the blossoming of the peas.

The border on Field Number 1 during 1933 was dusted with hand dusters at the peak of the weevil population. During 1934 the borders were burned with a weed burner and plowed under in a further attempt to eliminate the massed weevils.

<u>Results for 1932.</u> The experiment during 1932 was executed with the hope that the weevils would exhaust their egg laying capacities on the border plantings. No provision was made for any further control attempts. Table 44 presents the planting data for the fields under observation in 1932. The first of the border plantings was seeded on April 25 and the first of the main fields was sown on the 12th of May. The maximum spread between the first bloom in the borders and the first bloom in the main field was 14 days and the minimum spread was 11 days. The tabulated data on the movement of the weevil population in these fields are presented in Tables 45, 46, 47, and 48. Table 45 presents the data on an early planted field about which no border was planted. A study of this table shows the average infestation at its peak to be 695 weevils in 100 sweeps of a net at the edge of the field and 195 in the same number of sweeps 50 feet in from the edge.

The border was inadvertently plowed out in about half of experimental field No. 1 (Table 46), but the half that remained fronted on that side of the field nearest favorable hibernating quarters. A maximum number of 1415 weevils was collected in the border in 100 sweeps at the peak of the infestation and only eight were collected in the same number of sweeps adjacent to the main field in the border. The average for the peak in this field was 839 weevils in 100 sweeps in the border and only 24 adjacent to the border in a like number of sweeps. The average infestation in the border was 78.9 per cent and next to the border in the main field the infestation was 59.5 per cent adjacent to the border. A study of the data for the portion of the field not surrounded by border showed the infestation to be much less. This may be due to the fact that this portion of the field was the most distant from the principal source of infestation, or to the fact that the borders were detrimental.

The holding power of the borders is again shown in Table 47. One collection in this field showed 1082 weevils in 100 sweeps of a collecting net in the border and only one in a like number of sweeps in the main field not over three feet from the border. The average for 100 sweeps was 584 collected in the border and five next to the border in the main field. The peak of the infestation apparently had not been reached but differentiation between border collections and field collections for the total average number of weevils caught was greater on the next sweeping. This table also shows very nicely the movement of the weevils into the main field. The infestation division of this table is also interesting, for it shows positively that border plantings must be eliminated if they are to be an aid in control.

Table 48 is presented to show that a sharp contrast does not always exist between the number of weevils in the border and in the main field. It is felt, however, that this was due to the fact that collections were not made at the peak of the infestation.

Table 44

Planting Data on Trap Crop and Weevil Control Experiment, 1932

Experimental Field	Acres in Field	Border				Main Field				Difference in Blooming Dates
		Planted	Up	First Bloom	Variety	Planted	Up	First** Bloom	Variety	
1	70	4/25	5/7	5/9	Alaska	5/14	5/27	6/23	First and Best	14 Days
2	30	4/25	5/7	6/10	First and Best	5/12	5/22	6/21	First and Best	11 Days
4	90	4/30		6/13	First and Best		5/30	6/25	First and Best	12 Days
5*	25	Check. No border planted.				4/25	5/7	6/10	Alaska	

* No border about fields.
**Dates approximate.

Table 45

Weevil Population and Infestation Studies on an Early Planted Field (Experimental Field No. 5, Check). Moscow, Idaho, 1932.

Date Sweepings Were Made[1] 6/7 Edge	6/7 50 feet in	6/7 Center	6/9 Edge	6/9 50 feet in	6/9 Center	6/14 Edge	6/14 50 feet in	6/14 Center	6/22 Edge	6/22 50 feet in	6/22 Center	7/1 Edge	7/1 50 feet in	7/1 Center	Weevil Examination[2] (Per Cent Weevily) Edge	50 feet in	Center
0	*	*	2	2	1**	220	54	17	45	70	30**	84	119	66**	44.0	43.0	11.0
0			6	5		396	256	19	246	140		34	20		58.6	60.5	13.0
0			11	10		888	410	14	537	307		91	37		82.0	69.5	11.4
0			27	9		1260	730		649	782		91	59		80.0	78.9	
1			36	11		1333	216		609	1112		104	20		89.6	82.0	
0			85	21		748	42		476	684		131	12		79.4	31.2	
0			15	1		173	58		59	35		60	10		90.0	43.3	
0			1	4		848			127	75		62	16		80.4	50.0	
1			4	3		391			84	42		52	4		38.6	17.2	
Av. .1			21	7	.3	695	195	17	315	361	10	78	31	22	71.4	52.8	11.1

1 Figures indicate the number of weevils per 100 sweeps of a fifteen-inch collecting net.
2 500 peas examined.
* No sweepings made.
**300 sweeps taken.

Table 46

The Influence of a Trap Crop of Peas Planted as a Border on the Control of the Pea Weevil (Experimental Field No. 1), Moscow, Idaho, 1932.

	Date Sweepings Were Made[1]																		Weevil Examinations[2] (Per Cent Weevily)			
	5/31			6/7			6/10			6/18			6/24			7/2						
	Border	Next Border	Center	Border	Next Border	Center	Border	Next Border	*** Center	Border	Next Border	*** Center	Border	Next Border	*** Center	Border	Next Border	Center	Border	Next Border	80 feet in.	Center
	0	*	*	4	*	*	118	1	0	1227	55	51	256	129	145	14	184	74	95.5	31.0	24.0	9.58***
	0			3			58	0		1041	45		305	81		2	110		82.4	61.2	36.4	
	0			1			97	0		597	11		303	85		9	189		96.0	32.6	52.0	
	0			2			32	0		473	14		503	182		26			95.2	58.0	16.2	
	0			0			133	1		614	11		326	214		16	527		86.4	80.2	64.6	
	0			0			159	2		780	28		507	247		50	363		17.2	60.4	67.5	
	0			2			137	0		1306	9		654	323		31	469		83.7	66.4	53.2	
	0			1			147	0		1415	8		465	149		23	332		84.2	75.4	53.2	
	0			3			206	0			38		328	122		57	341		77.3	70.2	45.0	
Av.	0			2			121			839	24		405	170		23	279		78.9	59.5	45.5	
	**			**			**			**			**			**			**	**	**	
										14	7		106	49		43	53			51.2	26.7	
										13	3		21	11		14	34			19.5	34.0	
										3	0		12	11		33	13			10.0	17.6	
										19	0		54	4		39	4			67.0	11.5	
										6	1		25	2		9	5			85.0	4.2	
										0	2		43	11		45	29			12.5	22.8	
										6	1		53	36		30	30			80.0	26.4	
Av.									0	9	2	5	45	16	14	30	24	7		43.7	20.4	

* Peas too small to sweep.
** No border present below this work.
***Number of weevils per 1000 sweeps.
1 Figures indicate number of weevils per 100 sweeps of a 15-inch collecting net.
2 500 peas examined.

Table 47

The Influence of a Trap Crop of Peas Planted as a Border on the Control of the Pea Weevil (Experimental Field No. 4), Moscow, Idaho, 1932.

Date Sweepings Were Made[1]																		Weevil Examinations[2] (Per Cent Weevily)			
6/7			6/10			6/17			6/25			7/5			7/14						
Border	Next Border	Center	Border	Next Border	Center	Border	Next Border	Center	Border	Next Border	Center	Border	Next Border	Center	Border	Next Border	Center	Border	Next Border	50 feet in from border	Center
1	*	*	12	*	*	535	6	**	472	151	3	175	301	21	14	74	42	35.1	63.6	50.0	10.7
0			6			355	7	4	459	89	5	180	306	10	45	123	60	66.8	60.4	37.2	9.1
0			15			358	4		388	121	0	184	308	8	24	140	36	66.5	73.0	54.4	29.0
0			24			323	1		559	149	2	293	505	14	75	245	32	76.6	78.2	70.0	14.0
0			16			553	15		791	247	11	327	546	6	67	520	13	41.0	76.0	75.5	23.6
0			13			1082	1		729	241	2	372	461	7	80	422	22	33.2	74.6	86.0	14.2
0			16			684	4		994	224	11	265	370	9	114	469	18	72.0	81.4	80.0	17.6
0			5			787	11		1188	385	2	305	633	4	98	474	23	64.8	87.0	79.7	19.2
0			11			669	2		793	250	18	360	506	19	83	301	12	82.2	82.6	78.4	44.8
0			47			542	2		751	214	13	335	330	22	97	259	8	87.4	72.6	82.4	14.6
0			19			780	5		998	296		298	481		39	374		78.8	85.0	77.7	
0			17			1241	11		1011	334		252	250		98	349		79.2	85.0	79.8	
0			17			467	1		420	124		159	228		64	272		86.1	84.2	64.0	
0			34			788	6		507	170		131	320		15	231		75.6	71.6	59.6	
1			14			689	5		475	143		210	467		42	458		69.2	67.6	65.0	
0			5			914	2		490	140		314	495		48	433		56.6	67.2	82.6	
0			6			361	7		587	231		464	427		127	403		68.6	77.3	77.8	
0			8			590	7		756	284		129	372		97	314		74.0	71.0	68.4	
1			12			167	4		506	111		311	422		109	398		31.8	77.0	59.2	
1			15			302	3		511	264		182	281		52	109		29.6	61.5	57.0	
0			11			218	7		740	213		137	123		12	59		59.3	63.0	48.0	
0			3			488	3		395	92		59	156		5	48		51.0	34.5	23.0	
0			13			562	1		559	72		65	123		0	29		56.0	34.9	37.0	
Av..2			14			584	5	.4	655	197	7	239	365	12	64	274	26	62.6	70.7	64.9	19.7

[1]Figures indicate number of weevils per 100 sweeps of a 15-inch collecting net.
[2]500 peas examined for each per cent indicated. *Peas too small to sweep. **1000 sweeps.

Table 48

The Influence of a Trap Crop of Peas Planted as a Border on the Control of the Pea Weevil (Experimental Field No. 2), Moscow, Idaho, 1932.

	Date Sweepings Were Made*																		Weevil Examinations** (Per Cent Weevily)			
	6/7			6/10			6/18			6/24			7/7			7/20						
	Border	Next Border	Center	Border	Next Border	Center	Border	Next Border	Center	Border	Next Border	*** Center	Border	Next Border	Center	Border	Next Border	Center	Border	Next Border	50 feet in	Center
	0	0	0	12	0	0	225	33	3	227	61		138	184	4	19	15	8	64.2	40.0	10.1	0.6
	0	0	0	3	0	0	219	10	3	311	169		18	46	6	0	53	8	49.0	21.4	3.0	4.0
	0	0	0	36	0	0	246	9	2	240	406		31	109	0	17	27	9	61.4	52.6	7.9	3.0
	0	0	0	22	0		186	24		279	307		61	182		4	5		53.5	47.0	13.3	
	2	0		67	3		304	17		287	87		3	51		0	76		17.0	31.6	11.7	
	1	0		33	0		463	63		223	309		6	99		43	93		43.7	36.9	24.0	
	5	0		37	0		362	75		144	222		8	106		0	69		69.4	49.5	31.0	
	0	0		277	3		617	76		664	115		100	145		6	2		78.0	74.2	44.0	
	1	0		171	3		203	58		231	61		11	79		0	15		49.6	50.0	41.0	
Av.	1	0	0	73	1	0	314	41	3	323	193		42	111	3	10	39	8	53.9	44.8	20.6	2.5

* Figures represent results from 100 sweeps with a 15-inch collecting net.
** 500 peas examined.
***Data missing.

<u>Results for 1933.</u> The experiment was repeated again during 1933 with the understanding that burning equipment would be provided to attempt to destroy the weevils. Several factors operated to prevent the construction of the burner after the borders were planted. The weevil situation was not as threatening as during 1932 so the borders were allowed to develop. One of the borders (Table 50) was dusted with hand dusters and the other (Table 49) was untreated.

The borders were planted on April 21 for Field No. 1 and April 15 for Field No. 2. The main crop was planted in both fields the week of May 4. The border on Field No. 1 bloomed on June 11 and was followed on June 14 by the first bloom in the main field. The border of Field No. 2 bloomed first on June 10 and was followed on June 15 by the first bloom in the main field.

The difference between the blossoming dates of the borders and the main fields was much less in 1933 than in 1932. A difference of only three days in Field No. 1 was observed and of only five days in Field No. 2. Weather conditions were responsible for this slight difference in the blooming dates, for the seeding dates were over 17 days apart. A cold wet period held back the development of the borders until the seeding of the main fields was necessary. Then the borders and the fields developed together.

Even with this small difference in blooming date a striking difference was apparent in the number of weevils collected in the border in 100 sweeps of the collecting net compared to the number collected in the main field immediately adjacent to the border. The maximum difference occurred in Field No. 2 where 352 weevils were caught in 100 sweeps in the border and only six in a like number of sweeps in the main field. The average collections for this date gave 110 weevils in the border in 100 sweeps and only

Table 49

Influence of a Trap Crop of Peas Planted as a Border on the Control of the Pea Weevil. Experimental Field No. 1 (Moscow, Idaho, 1933).

	Sweeping Record*															Weevil Examinations** (Per Cent Weevily)			
	6/14/33			6/19/33			6/23/33			7/4/33			7/13/33						
	Border	Next Border	Center	Border	Next Border	Center	Border	Next Border	Center	Border	Next Border	Center	Border	Next Border	Center	Border	Next Border	60 feet in	Center
	67	4		36	4	0	0	0	0	9	8	0	0	1	0	17.2	7.6	4.4	0.0
	62	4		14	0	0	2	6	1	4	2	1	0	4	0	13.0	2.0	0.2	0.0
	34	3		27	12	0	1	0	1	6	8	0	0	3	1	12.4	13.8	1.4	0.0
	78	10		44	6	0	5	2	0	6	14	0	0	7	0	7.4	6.2	3.2	0.0
	61	1		36	9	3	0	1	0	3	4	0	0	3	0	55.2	14.4	5.0	0.2
	74	4		22	11	0	0	1	0	15	2	0	0	3	0	10.6	6.4	2.4	0.0
	14	4		8	6	0	8	4	2	2	7	1	17	2	0	10.4	6.2	1.4	1.0
	99	3		20	1	3	7	23	2	31	10	0	12	0	3	29.0	16.2	5.4	2.2
	30	0		37	3	1	4	23	6	9	8	0	5	0	0	23.6	12.8	3.0	0.0
	122	7		50	4	0	2	16	1	7	8	0	0	2	0	20.8	10.6	0.0	1.8
	68	2		50	3		7	12		2	29		2	1		29.0	20.0	1.2	
	64	4		61	7		0	3		7	22		5	2		12.0	17.4	0.8	
	71	2		22	6		0	1		2	5		0	2		21.0	7.6	1.6	
	54	5		20	3		-	-		6	4		2	20		30.6	9.8	0.0	
Av.	64	4		32	6	0.5	3	7	1	8	9	0.1	3	4	0.3	20.8	10.8	2.1	0.5

* Number of weevils per 100 sweeps of a fifteen-inch collecting net.
**500 weevily peas examined.

Table 50

Influence of a Trap Crop of Peas Planted as a Border on the Control of the Pea Weevil. Experimental Field No. 1 (Moscow, Idaho, 1933).

Sweeping Record*															Weevil Examinations** (Per Cent Weevil-Infested)			
6/12/33			6/19/33			6/23/33			7/5/33			7/14/33						
Border	Next Border	Center	Border	Next Border	Center	Border	Next Border	Center	Border	Next Border	Center	Border	Next Border	Center	Border	Next Border	50 feet in	Center
41	0		3	0	2	0	0	0	0	0	0	0	0	1	2.0	1.4	4.4	1.0
68	2		7	1	0	2	6	1	2	3	1	3	0	0	2.2	1.4	.8	0.0
50	1		9	1	0	1	0	1	0	0	0	0	0	1	2.4	.8	.0	7.8
53	1		15	1	0	5	2	0	1	0	0	0	0	3	.8	.2	.2	2.6
51	1		15	3	0	0	1	0	4	0	0	0	1	0	.8	.2	1.4	2.8
32	0		3	1	0	0	1	0	8	10	1	2	5	0	1.8	.6	.2	1.2
206	2		23	5	2	8	4	2	5	6	0	0	11	0	1.2	3.8	3.4	3.6
352	6		72	50	4	7	23	2	4	8	0	0	3	0	9.2	4.8	7.4	1.2
169	5		69	34	5	4	23	6	0	18	0	1	3	0	3.0	4.4	5.4	2.4
124	15		23	34	0	2	16	1	0	4		0	1	1	1.8	7.0	6.2	
131	1		45	1		7	12		0	0		0	0		10.0	7.0	8.8	
41	1		6	1		0.	3					0	7		1.6	7.8	4.6	
															1.6	3.4	2.0	
Av. 110	3		24	11	1	3	8	1	2	4	0.1	0.5	3	0.5	3.2	3.6	3.7	2.5

* No. of weevils per 100 sweeps of a fifteen-inch collecting net.
**500 peas examined.

three in the main field. The results for Field No. 1 were not so definite, because a poor stand of peas, feeding of ground squirrels, and weeds all operated to make the border ineffective.

The border of Field No. 2 was dusted with calcium arsenate on June 15 and again on June 22. The results were very interesting, but not convincing. Field counts of collected weevils showed that the average population in the border had dropped from 110 per 100 sweeps in the border to 24 in a like number. An increase from three to 11 weevils occurred in 100 sweeps in the main field. Another drop occurred in the border after the second dusting. This time the average in the borders dropped from 24 to three in 100 sweeps and the numbers in the main field next to the border declined to eight from 11.

A comparison of the results of this field with Field No. 1 showed that a decrease in numbers collected in this field occurred also, but the decrease was not as marked as in the dusted field. Also the weevil damage was greater in Field No. 1 even though the peak population was approximately five times less.

Results for 1934. Experience had shown in 1932 and again in 1933 that some means positive in action was necessary to kill the weevils attracted to the borders on border plantings, otherwise they were more of a menace to farmers than a benefit. Two methods, burning and plowing, were used during 1934 against the weevils. The burner used in these experiments was constructed in coöperation with and operated by Mr. Orve K. Hedden of the United States Department of Agriculture, Bureau of Agricultural Engineering, in coöperation with the Department of Agricultural Engineering of the University of Idaho.

Results with the burner. It was comparatively easy to visualize a burner, pushed ahead of a crawler type of tractor, killing completely all the weevils in its path by burning, but field topography, the mass of pea vegetation, and the habits of the weevil presented difficulties that made very difficult the conversion of the visualized burner into actuality.

The topography of the Palouse region, where the experimental work was carried on, made the requirements for flexibility in the construction of the burner very severe. Wheel type tractors are practically never used in the territory because of the steep side hills. Crawler type tractors are in general use and many of them are equipped with wide hillside type tread. Shallow washes, resulting from soil erosion, must be crossed. The first furrow slice on the fields in this locality is usually thrown toward the outer edge of the field so there is a considerable ridge near the margin of most fields on which a portion of the border may be planted. It is necessary that the burner be completely flexible in order that the constantly changing surface of the field may be followed closely. The peculiar motion of the crawler type tractor also demands flexibility.

Pea vine growth varied from 12 to 24 inches in the borders. This variation in vine growth made it necessary for the machine to be constructed in such a way that the burner hood could be readily raised or lowered as the situation demanded.

The heavy succulent growth of the pea vines requires that special provision be made for increased generating surface and combustion space be provided. The dense growth also makes it desirable and necessary that the flames issue from the combustion tubes with a considerable blast in order that the hot gases will be driven to the lower parts of the plants.

Pea weevils are easily actuated and fly readily or drop to the ground and feign death when the pea vines are disturbed. These characteristics led to the experiments being conducted at night and made it necessary that the apparatus be mounted ahead of the tractor.

Plate 24 shows a front view of the apparatus and Plate 25 shows a rear view of the equipment built by Mr. Hedden to meet these specific demands. The burner finally used was a tractor powered generator type. Fourteen burner jets spaced 10 inches apart made up the burner unit. Each of the burner jets was surrounded by a three-inch combustion tube. The oil under pressure passed through about 30 feet of generating tubes beneath the hood and issued from the burner jets as a gas. The gas under pressure ignited at the mouth of the combustion tubes. The flames that issued from the combustion tubes were about 20 inches long. The fire was confined within a hood that was three feet long, 10 feet wide and 12 inches high. The hood was built of heat resisting metal to withstand the terrific heat generated by the burners.

Flexibility was attained by attaching the burner to the tractor frame and suspending it by spring tension from the motor supports. This spring tension, combined with 360 degree caster wheels, had the effect of floating the apparatus ahead of the tractor. The apparatus worked so efficiently that on one occasion the burner was pushed into a V-shaped erosion gully, the upper edge of which was two feet higher than the lower edge, which must be crossed, and the apparatus was pushed across with ease. Plate 26 shows a view of the burner in action on one of the borders.

The fuel tanks were carried on a frame fastened to the rear of the tractor. A special apparatus inserted into the bung of the fuel barrels enabled oil to be pumped directly from the barrels. Power was supplied by a 3/4 H. P. "Maytag" engine. A flexible metal hose conducted the fuel from the barrels to the generator. Plate 25 shows a view of the fuel tanks and pumping equipment.

The equipment was tested on 13,600 feet of border 22 feet in width and on 8,300 feet of eleven-foot border. Results for Field 1 are presented for they embody the results obtained on Field 2. Data of interest on the burning itself follow:

Time to generate and start burner - - - - - - - - - - 8 minutes

Tractor speed - - - - - - - - - - - - - - - - - - .88 mile per hour

Kind of fuel used - - - - - - "Diesel Oil" 34.8° A.P.I. 60°/60°

Diameter of jet orifice - - - - - - - - - - - - - - - .0625 inches

Fuel line pressure- - - - - - - - - - - - - 40 lbs. per sq. in.

Cost of fuel per gallon - 0.10

Cost of fuel per mile of eleven-foot border - - - - - - - $2.97

Plate 26 shows a view of the burner in operation during a preliminary test.

The tests were conducted on a 218 acre field shown in Plate 27. Places at which periodic examinations of the weevil infestation were taken are shown by plus signs.

The borders were planted on March 20, a month earlier than we have been able to seed them previous to this spring. Seeding was started on April 14 on the main portion of Field No. 1 and the planting of the remaining portion was started on May 6. Such a variation in the seeding dates provided, in reality, two experimental fields within the border. The two seedings are separated by the dotted line on the field map and are labeled A and B.

The first blossoms appeared in the border on May 7 and in the first planted section of the main field on May 25, and the first bloom in the second section appeared on June 9. This gave a spread of 18 days on planting A and a spread of 33 days on section B.

Burning was started on the night of May 25 and completed on the night of May 27. Mechanical difficulties caused a suspension of operations on the night of the 26th. Table 51 presents the growth data for this field.

Table 51

Growth Data for Trap Crop Border Plantings, Field No. 1, Moscow, Idaho, 1934

Date	Growth of Border	Main Crop, Section A
March 20, 1934	Planted.	
April 9	Up.	
April 16	2" - 3" high.	Planted.
April 23	3" - 5" high.	
April 30	5" - 7" high.	Up.
May 7	8" - 11" high, first buds.	1" - 2" high.
May 15	12" - 16" high, well in bloom.	2" - 5" high.
May 25-28	Border burned.	5" - 10" high, first blossom.
Variety	Alaska.	First and Best.

The efficiency of the burning was determined in three different ways: first, by infestation counts taken by sweeping the field at designated localities before and after burning; second, by cage collections made by placing cages over areas in the border and in the main field before and after burning; and third, by collecting weevils by hand immediately after burning.

The burning did not prove to be so effective as expected. Weevils were caught in cages placed over the pea vines immediately after the burner had passed, as is shown in Table 52. The figures represent the number of weevils collected on 12 square feet of the field surface.

Table 52

Cage Collections of Weevils in the Border and Main Field Before and After Burning, Moscow, Idaho, 1934.

Border		Main Field	
Before Burning	After Burning	Before Burning	After Burning
42[1]	21[2]	19	33
26	12	20	12
114	29	17	29
108	11	4	11
117	34	2	34
107	17	22	17
66[4]	6[5]	0[3]	0[3]
57	6	0	0
41	8	0	0
35	11	0	0
31	3	0	0
15	13	0	0

[1]Examined May 25; the day of burning.
[2]Examined May 27.
[3]Peas too small to attract or hold weevils.
[4]Examined May 27; the day of burning.
[5]Examined May 29.

The data in this table were collected on two different days, for the border about half of the field was burned on May 25 and the remaining half on June 27. It is feared that the cages did not catch all the weevils that survived the burning, for some time elapsed before the slow-moving tractor advanced over the burned localities, allowing a cage to be placed, and several times living weevils in flight were caught by those driving the tractor and by spectators opposite the machine. Also on the night of May 27, 16 weevils were taken directly from blooms over which the flames had passed and every one was alive. This same night, with the aid of a flashlight, 100 weevils found on the ground were examined to determine the mortality. Thirty-four of them flew away apparently unharmed. A number of weevils (562) were then collected from the ground to determine the number that would recover. Out of the 562 collected, 115 or 20.4 per cent recovered sufficiently to fly away. These figures indicate that many of the weevils survived the burning.

The maximum number of weevils caught in the border in 100 sweeps before burning was 1365. The average in the border for section A for 100 sweeps was 737.0 and for the main field next to the border 46.8 before burning. The number of weevils already in the main field before burning, too large to hope for a completely successful experiment, was directly due to two factors: First, the stand of peas was not too good in the border and at the peak of the infestation every blossom was mutilated; this, it is believed, was di-directly responsible for the number of weevils present in the main field; second, some scattered volunteer or aberrant types bloomed before burning could be started. Sweeping records for Sections A and B about which the border was burned are presented in Table 53. The damage done by the weevils is shown in Table 54. An examination of these tables corroborates the data previously presented, for the average of the collections made adjacent to the border in section A jumped from 46.8 before burning to 113.3 after burning.

Table 53

Sweeping Record from Border Trap Crop Experiment, Moscow, Idaho, 1934

		Before Burning											
		May 10, 1934			May 14, 1934			May 18, 1934			May 22, 1934		
	Section	Border	Inside	Center	Border	Inside	Center	Border	Inside	Center	Border	Inside	Center
	1	8	1	1	363	1	1	255	1	2	741	1	2
	2	20			418			519			1360		
B	3	1			292			230			1365		
	4	-			104			69			1261		
	5	34			312			546			1020		
	21	47			211			325			872		
Av. for B		18.3			283.3			324.0			1103.1		
	6	143			286			159	2		1146	108	
	7	56			516			559	2		1318	130	
	8	22			795			555	2		1221	57	
	9	144			508			1030	5		807	81	
	10	79			283			432	0		915	41	
	11	69			474			375	2		790	26	
	12	77			291			341	0		1177	21	
A	13	26			225			200	0		415	10	
	14	26			226			203	1		344	58	
	15	37			155			358	0		549	29	
	16	5			86			171	0		312	14	
	17	10			43			191	4		380	10	
	18	2			54			133	2		421	30	
	19	3			82			187	1		793	51	
	20	64			201			290	0		469	36	
Av. for A		50.8			280.5			345.6	1.4		737.0	46.8	
	22	52			171			358	1		653		
C	23	7			31			261			517		
	24	27			418			378			963		
Av. for C		22.0			206.6			332.3			711.0		
Field Av.		39.1			272.7			338.6	1.4		825.2	46.8	

Table 53 (Cont.)

		After Burning											
		May 28, 1934			June 9, 1934			June 16, 1934			June 25, 1934		
	Section	Inside	100 ft. in	Center	Inside	100 ft. in	Center	Inside	100 ft. in	Center	Inside	100 ft. in	Center
	1	[1]	[1]		10	4		2	14		2	0	
	2				43	3		43	12		17	0	
B	3				43	3		38	11		24	0	
	4				21	4		14	38		10	2	
	5				2	12		1	15		2	14	
	21				15	0		2	4		2	2	
Av. for B					22.3	4.3		16.6	15.6		9.5	3	
	6	177	110	5	274	168	2	289	208	2	176	134	5
	7	194	103	7	289	171	15	279	118	18	326	148	16
	8	175	197	8	234	286	19	285	230	12	112	143	15
	9	276	66	6	190	156	29	124	212	8	90	78	22
	10	170	26	8	122	49	16	382	80	6	94	66	11
	11	72	43	3	40	59	5	112	49	11	256	73	8
	12	75	30		69	45	5	74	44	9	125	15	3
A	13	44	12		37	21	2	24	18	5	24	3	6
	14	105	10		40	21	3	51	17	3	69	33	10
	15	66	22		78	19	10	58	23	1	53	10	2
	16	76	8		40	5		46	31		26	10	
	17	45	5		160	13		166	25		31	3	
	18	88	15		145	24		158	42		83	20	
	19	80	19		144	44		182	71		83	40	
	20	56	73		162	100		237	113		34	46	
Av. for A		113.3	49.2	6.1	134.2	78.4	10.6	164.4	85.2	7.5	105.5	54.8	9.8
	22	[1]	[1]		10	3		5	5		3	0	
C	23				32	4		12	4		2	2	
	24				14	0		6	8		1	2	
Av. for C					18.6	2.3		7.6	5.6		2	1.3	
Field Av.		113.3	49.2	6.1	91.8	50.3	10.6	107.9	57.8	7.5	68.5	35.1	9.8

[1]Peas too small to sweep.
[2]Peas large enough but no sweeps taken.
A=Border burned, peas planted in field April 15,1934.
B=Border burned, peas planted in field May 6, 1934.
C=Border plowed, peas planted in field May 6, 1934.

Table 54

Weevil Infestation in the Ripe Peas After Border Trap Crop Experiment, Moscow, Idaho, 1934

		Inside Border	50 Feet In	Center
	1	1.0 per cent	2.6 per cent	0.6 per cent
	2	29.4 " "	10.6 " "	0.4 " "
B	3	35.6 " "	14.8 " "	0.2 " "
	4	25.6 " "	14.4 " "	0.0 " "
	5	8.2 " "	14.4 " "	1.2 " "
	21	6.0 " "	1.0 " "	
Average for B		17.6 " "	9.6 " "	0.4 " "
	6	96.6 " "	78.6 " "	4.4 " "
	7	93.8 " "	94.0 " "	16.2 " "
	8	76.4 " "	87.6 " "	22.4 " "
	9	67.6 " "	84.6 " "	9.6 " "
	10	83.4 " "	86.0 " "	9.0 " "
	11	72.6 " "	62.4 " "	17.4 " "
	12	55.6 " "	37.0 " "	25.0 " "
A	13	38.2 " "	93.4 " "	15.6 " "
	14	47.8 " "	34.4 " "	19.6 " "
	15	56.8 " "	42.4 " "	21.4 " "
	16	36.6 " "	27.8 " "	
	17	65.4 " "	31.0 " "	
	18	78.8 " "	56.0 " "	
	19	76.4 " "	49.2 " "	
	20	74.2 " "	64.8 " "	
Average for A		68.0 " "	61.9 " "	16.0 " "
	22	4.0 " "	3.2 " "	1.6 " "
C	23	4.0 " "	3.2 " "	1.0 " "
	24	0.4 " "	3.0 " "	
Average for C		2.8 " "	3.1 " "	0.8 " "
Field Average		47.2 " "	40.7 " "	6.9 " "

A further examination of the data shows, however, that the number kept increasing for a period of 10 days after burning. This shows the possibility that weevils not attracted to the borders might still be moving into the field.

Section B, in which the peas in the main field were too small to sweep at the time of burning, collected a few weevils after burning, but the weevil infestation was materially lower.

Results with plowing. Approximately 1800 feet of border about a portion of this field (Section C) was plowed under during the night of May 25. The peas were covered by an ordinary five-gang plow set to plow at a depth of eight to nine inches. After the plowing, the ground was rolled three times with a cultipacker. The following table (Table 55) gives the results of cage collections of weevils on the border before and after plowing.

Table 55

Number of Weevils Collected in Cages on the Border Trap Crop Before and After Plowing, Moscow, Idaho, 1934

Cage	Caught Before Plowing	Caught After Plowing
1	249	5
2	101	2
3	89	1

The cages used in this experiment covered 36 square feet of surface. They were placed by chance on the border before plowing and were reset in the same locality but not on the same spot after plowing. Tables 53 and 54 present the sweeping record and the infestation record for Section C. A view of the border following plowing is shown in Plate 28.

DISCUSSION

Inasmuch as most of the pertinent facts relative to the data presented herein have been self-evident and the importance of certain of the facts has been fully discussed, only those of chief importance will be mentioned again here.

The study of the biology of the pea weevil brought out several interesting and previously unknown facts about the habits of this insect that may have a bearing on its control. It was found that the insect could use almost any available cover about badly infested fields for hibernation. In fact eight weevils survived the winter season successfully under the debris on a field's surface. Consideration of this information indicates the importance of clean culture on the amount of weevil infestation. Some have reported success in reducing the amount of weevil infestation by the practice of clean culture based on this information.

Pea weevils were able to survive two winters and one crop season in hibernation and emerge at the start of the second growing season and lay fertile eggs. This bit of information casts much doubt on the utility of the oft repeated suggestion that the pea weevil can be controlled by withholding the seeding of infested peas for two winters. It also shows that it may be possible for weevils to survive two winters in hibernation out-of-doors and therefore makes further impractical the suggestion that the pea weevil can be controlled by withholding the seeding of peas for one season.

Field oviposition studies show that the pea weevil has a very long oviposition period. It was impossible to plant peas without obtaining some weevil damage if weevils were present in the locality. Individual plantings of peas were suitable for egg laying from the time pods appeared until the peas ripened. Thirty days was the maximum period over which peas must be protected from the pea weevil.

One of the frequent sources from which many pea weevils escape and find suitable hibernating places is from late harvested peas. The peas, in every case on which the life history of the insect has been followed, were ripe before the pea weevils were mature. The difference in time between the ripening of the peas and the emergence of the adults usually amounted to several weeks so the escape of weevils from late harvested peas can be blamed on negligence.

Farmers could also profit much by early harvesting and fumigation of their crop. Not only does early fumigation reduce the weight loss, but it also makes it possible to save some of the infested peas for seed purposes.

The importance of field shatter, as a source from which weevils that cause future damage are recruited is self-evident. The smallest loss of pea seeds per acre recorded was more than sufficient to seed the acre in a regular planting. The maximum loss was equal to the amount of peas harvested. Farmers who are careless with their harvesting actually pay with shattered peas to provide a supply of pea weevils to infest and ruin their next season's crop. Carelessness on the part of an inefficient farmer in harvesting is also important to the careful farmer, for the pea weevil often flies several miles from where it completed its life cycle.

Planting weevil-infested peas also serves to help the pea weevil find its host plant. Burying weevil-infested peas at planting depth kept only a few insects from emerging. Weevil-infested peas, unless they are fumigated, are of no use for seed purposes.

Stomach poisons appear to offer but little help in the control of the pea weevil. Seven applications of the chief stomach poisons applied at the rate of 20 pounds per acre failed to give sufficient control to pay for the treatment. Contact insecticides gave promise of control, but because of their cost compared to the value of the crop they were not tested.

Border trap crop plantings gave the greatest promise of a practical control method. The borders alone served mainly as a source of attraction to the weevils and were a menace. Burning the dense mass of vegetation to kill the weevils gave promise of control, but several important factors still stand in the way of success. The burner used did not have sufficient heat to scorch the vines quickly enough to kill the weevils. The addition of air pressure which might cause the flames to penetrate the mass of vegetation more readily would improve the chances of success. Burning, if it can be perfected, because of the speed at which it can be accomplished, would be the most efficient method of removing the trap crop.

Plowing the borders under in cases where the main field was planted later gave much promise of control. Very few of the buried weevils were able to come to the surface and the main crop was comparatively free from weevils. It seems entirely possible that a good measure of weevil control can be accomplished by delaying the planting of the main crop inside a border planting and plowing under the peas in the border planting when they reach the peak of their blooming period. Later planting can be accomplished, if it is not delayed too long, without much loss in yield if the field is cultivated when necessary before planting to conserve the moisture.

CONCLUSIONS

1. The pea weevil, Bruchus pisorum L., is a serious pest of peas that is endemic throughout the pea growing section of the Palouse territory of Washington and Idaho. The infestation for the area has fluctuated from 4.2 per cent to 20 per cent of the crop.

2. The pea weevil hibernates successfully in practically every situation affording some protection about the edge of the pea fields. Ponderosa pine appeared to be the best locality for survival. In some cases weevils were able to survive in the debris on the field's surface.

3. Pea weevils are able to pass two winters and one crop season in hibernation and to emerge at the start of the second crop season and lay fertile eggs.

4. Pollen of some kind is a necessary food of the adult pea weevil before it can begin oviposition. The insect starts egg laying after four to 14 days of feeding. A maximum of 735 eggs laid by one caged weevil was observed during the summer of 1932. The average was 452 for 12 individuals. The maximum oviposition period during this year was 83 days, the minimum 17 days, and the average was 47 days. The maximum recorded for 1933 was 326.

5. A study of field oviposition revealed that pea weevils are able to lay eggs throughout the period in which peas can be raised. The rate of oviposition decreases, but some eggs are laid throughout the period. Individual plantings of peas were found to be suitable for egg laying from eight to 30 days, depending on the time the peas were planted.

6. The incubation period of the weevil varied from 8 to 14 days in 1932 and the average was nine. During 1933 the period lasted from 5 to 14 days. The average length of the larval stage was 41 days in one series, the maximum was 56 days and the minimum 28 days. Three moults and four instars were found during the larval stage. During 1932, the insect spent approximately 12 days in the first instar, 6 to 8 in the second, 12 to 14 in the third, and 10 to 12 days in the fourth. The average length of the pupal stage during 1932 was 15 days, the maximum 27 days, and the minimum eight days. A summary of the data on 548 individuals showed that the insect completed its life cycle in an average of 65 days. Two parasites, Microdontomerus anthonomi Gwfd. and Eupteromalvs sp. were found. Parasites and predators do little to control the pest.

7. Weevil-infested seed peas were found to vary from 98.0 per cent to 1.00 per cent in viability, depending on the stage to which the pea weevil had developed when the seeds were fumigated. Weevil-infested peas lost as much as 22.2 per cent of their individual weight as a result of larval feeding.

8. Field shatter, volunteer peas and the seeding of weevil-infested peas were pointed out as the main sources from which the supply of weevils that infest the next season's crop is recruited. Field shatter reached as high as 50 per cent of the possible yield and much of it resulted from careless handling of the peas. Volunteer peas often serve as a source from which weevil population is built up, but during some years, as in 1933, no volunteer peas produced seeds in the Palouse area. Planting weevil-infested peas is useless for the weevils emerge readily from planted peas

and the peas do not grow.

9. Cage experiments showed that from 0.9 to 3.7 per cent of the weevils in infested peas were able to come to the surface from a depth of eight inches. Field tests showed that 2.63 per cent of the weevils were able to emerge after being buried to a depth of from 8 to 9 inches.

10. Laboratory and field tests with stomach poisons applied as dusts gave little promise of control. Contact insecticides gave some promise of control.

11. A study of the time of planting during 1933 showed all plantings to be heavily infested, with the greatest damage (59.6 per cent) recorded on the eighth planting. Results for 1934 showed a decline in the amount of damage after the second planting to the last. The decrease in weevil damage was offset by a decrease in yield.

12. Border trap crop plantings, seeded about three weeks earlier than the main crop, seemed to offer the best control possibility. The border plantings to be effective must be eliminated before the peas in the main field blossom. Plowing is the best method used to destroy the border plantings effectively.

SUMMARY

1. The pea weevil, Bruchus pisorum L., is a serious menace to the pea industry in the Palouse section of Washington and Idaho.

2. Several new and important points in connection with the hibernation habits of the insect are discussed.

3. Field and laboratory tests to determine the length of the oviposition period of the pest are reported.

4. The length of time an individual planting and individual pods were acceptable for egg laying were determined and results presented.

5. Life history studies on 779 individuals are presented. Laboratory experiments were paralleled by field studies.

6. Parasites and natural enemies of the insect are discussed.

7. The loss in weight and in viability caused by the feeding of the larvae are pointed out.

8. Field shatter, volunteer peas, and the seeding of weevil-infested peas are shown to be the principal factors contributing toward the maintenance of the pea weevil problem.

9. Field and laboratory tests with insecticides are discussed.

10. The use of border trap crop plantings as a pea weevil control method is described. The comparative efficiency of burning the borders and plowing them under is discussed.

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VITA

I, Tom Albert Brindley, was born at Madison, Wisconsin, on November 18, 1906, the first child of Marie Pauline Albert Brindley and William Arthur Brindley. At the age of six years I entered the public grade school at Fort Dodge, Iowa, and graduated after uninterrupted attendance from high school of this city in 1924. The next two years were spent in attendance at the Fort Dodge Junior College from which I was graduated in 1926. This same year I entered Iowa State College with a junior rating. At this institution I majored in entomology under the guidance of Dr. C. J. Drake and Dr. C. H. Richardson.

The degree of Bachelor of Science was granted to me from this institution in 1928 and the Master of Science degree in 1929. Following my graduation in 1929 I continued my graduate research work. I was employed during this period as a part time laboratory assistant in the Entomology Department and as an experiment station assistant during the summer months.

I was employed in June, 1931, by the United States Department of Agriculture Bureau of Entomology to study the biology and control of the pea weevil at Moscow, Idaho.

PLATES

Plates (Cont.)

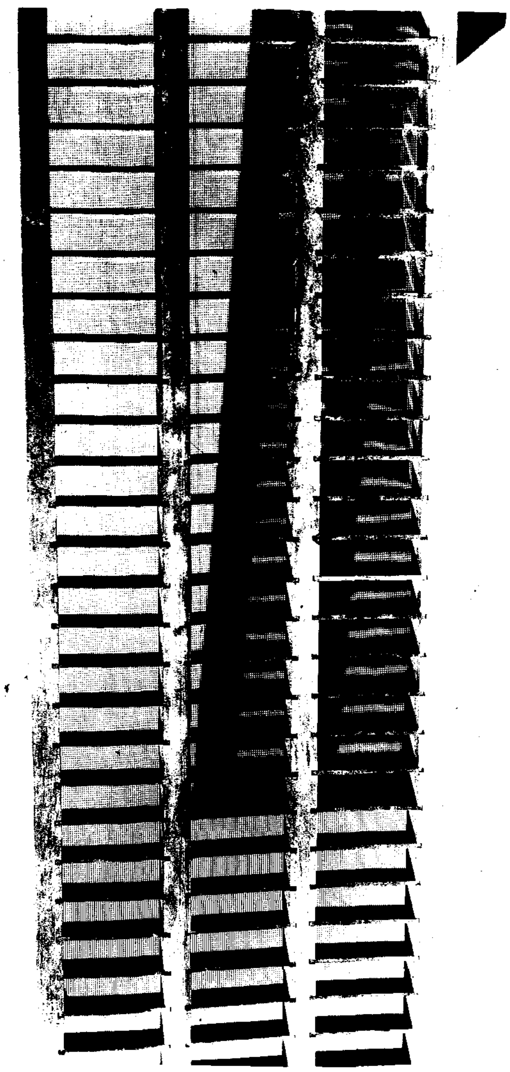


Plate 1. Wire bottomed tray used to hold weevil-infested peas for life history studies.

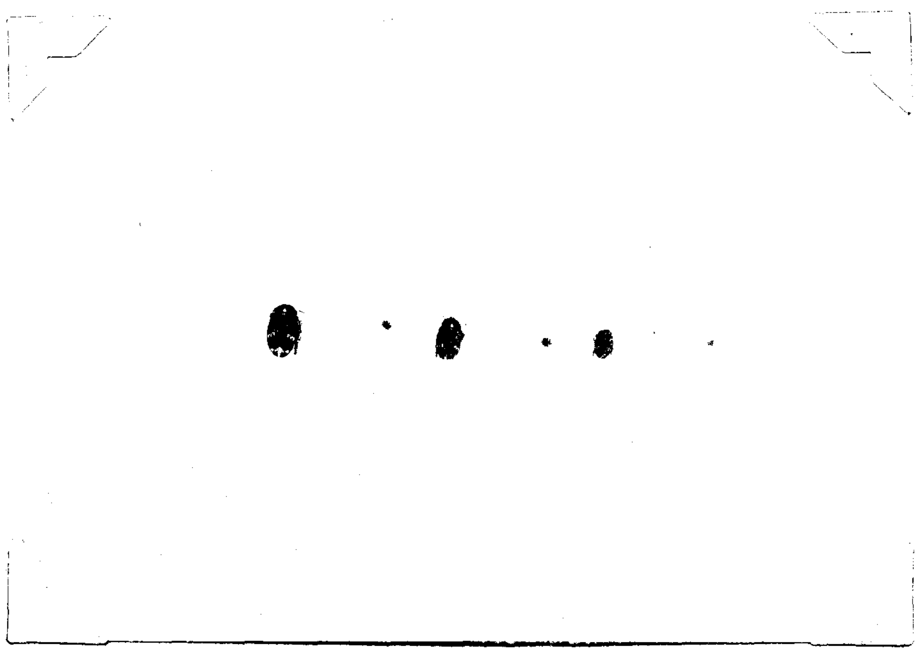
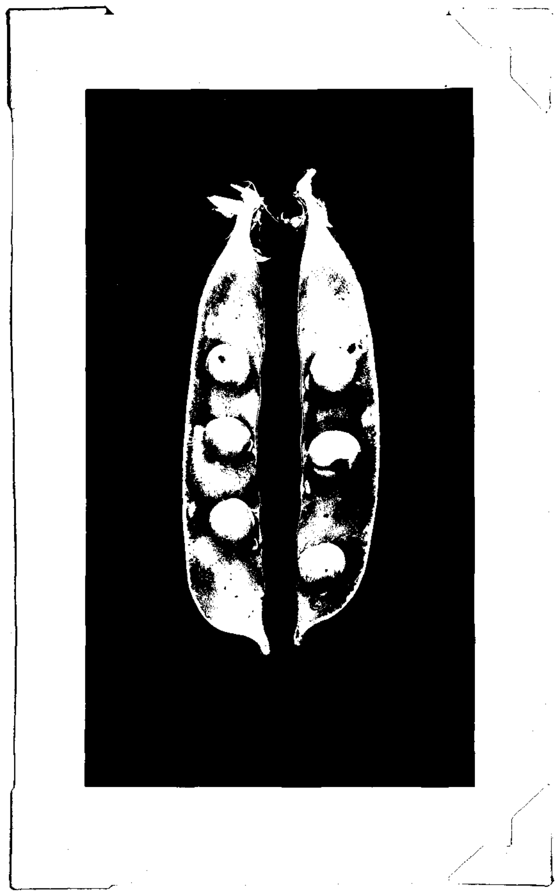
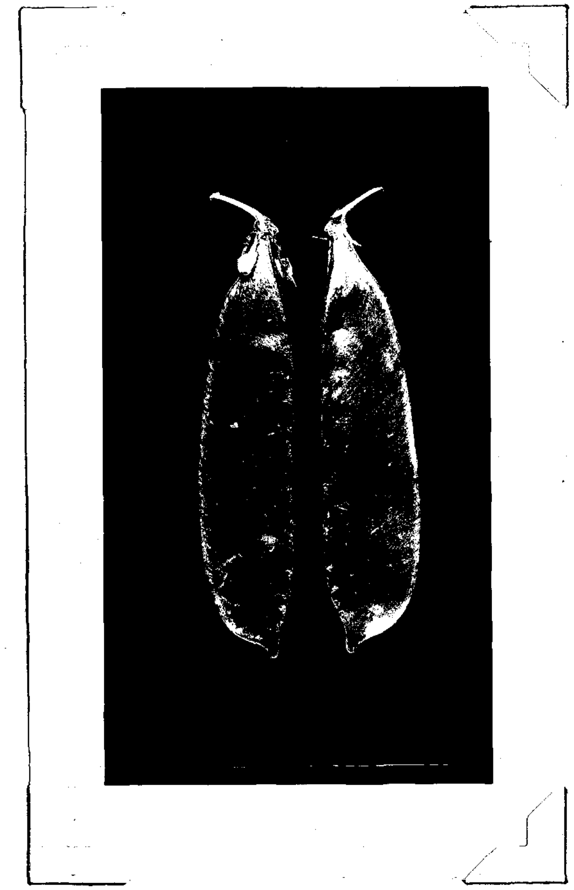


Plate 2. Variation in the size of pea weevil adults.
Figures x1.6 actual size.



"A"



"B"

Plate 3. Size of peas in which pea weevils can develop. Figure "A" shows a pod of peas actual size in which pea weevils developed. Pod "B" shows a pea pod which was picked while still green and flat and in which a pea weevil completed its development. Small weevils develop in small peas.

Plate 4. Pea weevil adult in a typical position on a pea blossom.

Plate 5. Pea weevil adults feeding on the bases of the calyxes of pea blossoms. This is a typical feeding position.

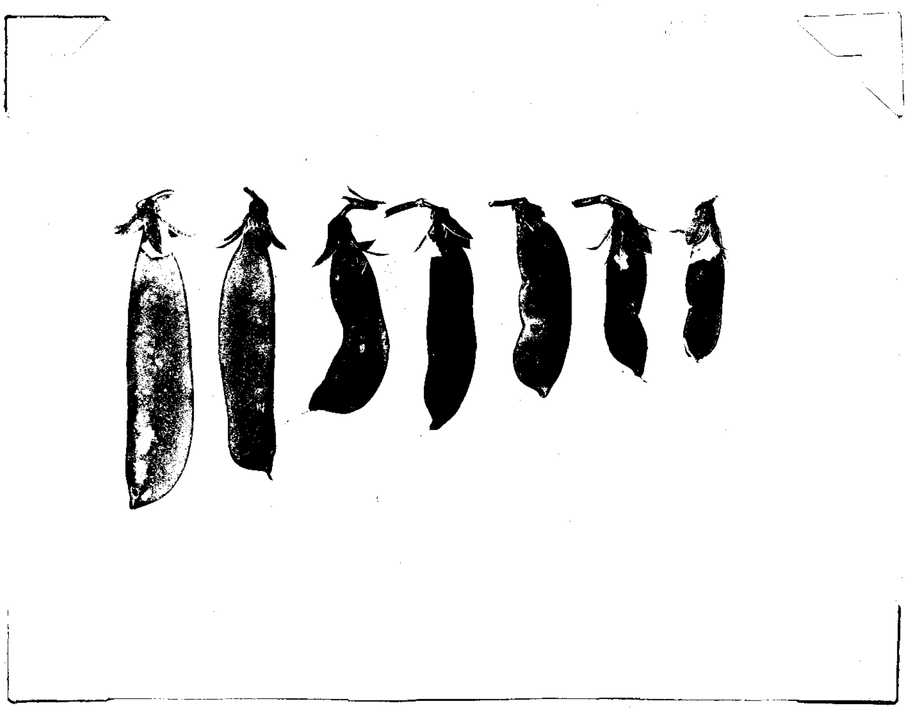


Plate 6. Injury to pea pods resulting from the feeding of adult weevils.

Plate 7. Injury to calyxes resulting from the feeding of adult pea weevils.

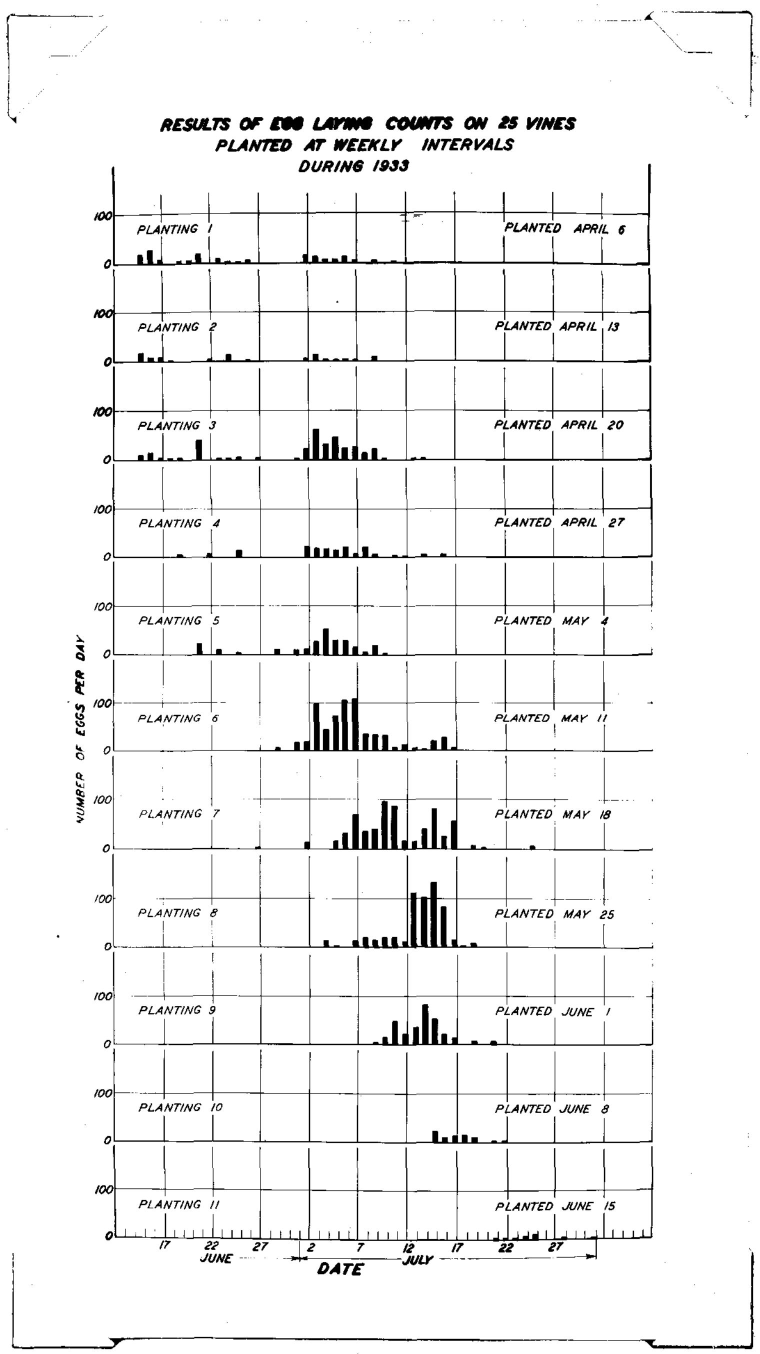


Plate 8. Graph showing a summary of the egg deposition by pea weevils on 11 consecutive weekly plantings of Alaska peas.

Plate 9. Pea weevil ovipositing. Photo enlarged to approximately natural size.

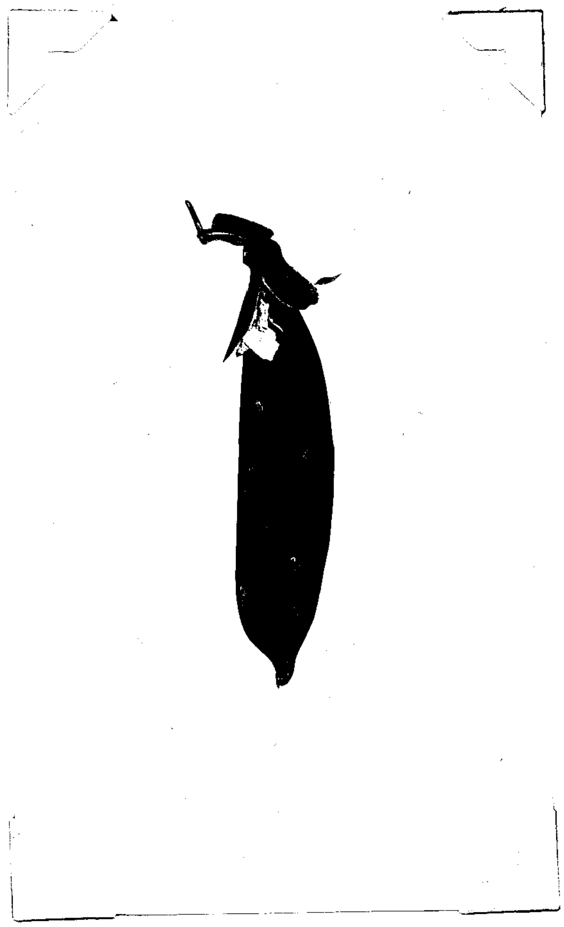


Plate 10. Pea pod showing eggs for the study of the length of the incubation period marked by a ring of India ink.

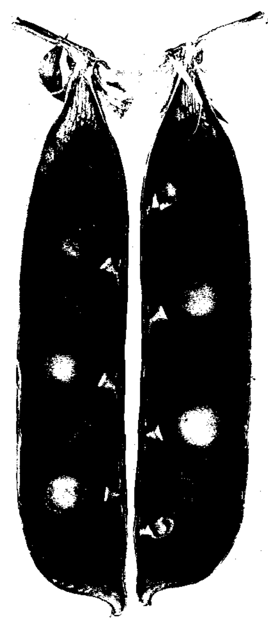


Plate 11. Scars, commonly known as stings, mark the place where a weevil larva has attempted to enter or entered a pea. The black spot on the pea is the entrance scar.

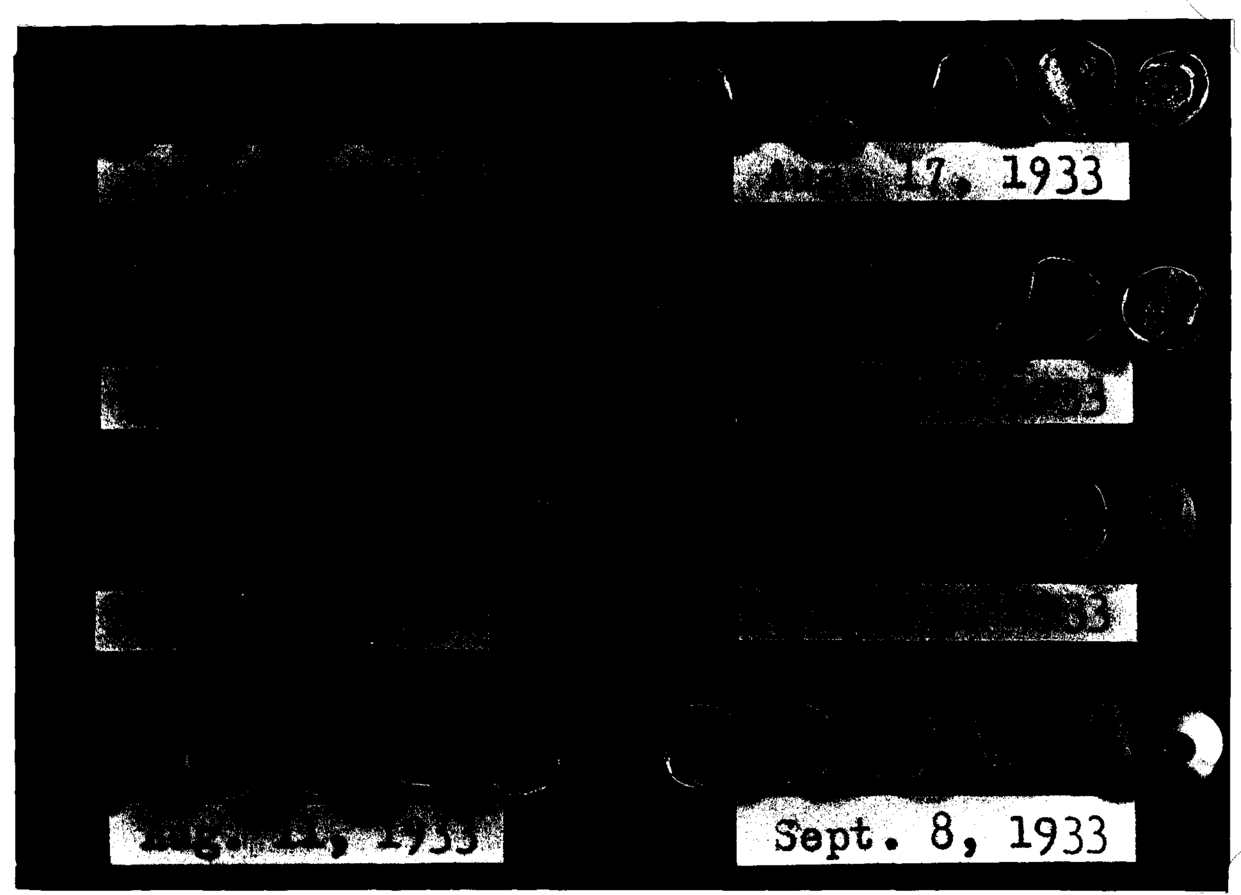


Plate 12. A series of peas split at weekly intervals to show the damage caused by the feeding of the larva of the pea weevil. The largest and the smallest as well as the average sized cavities are shown.

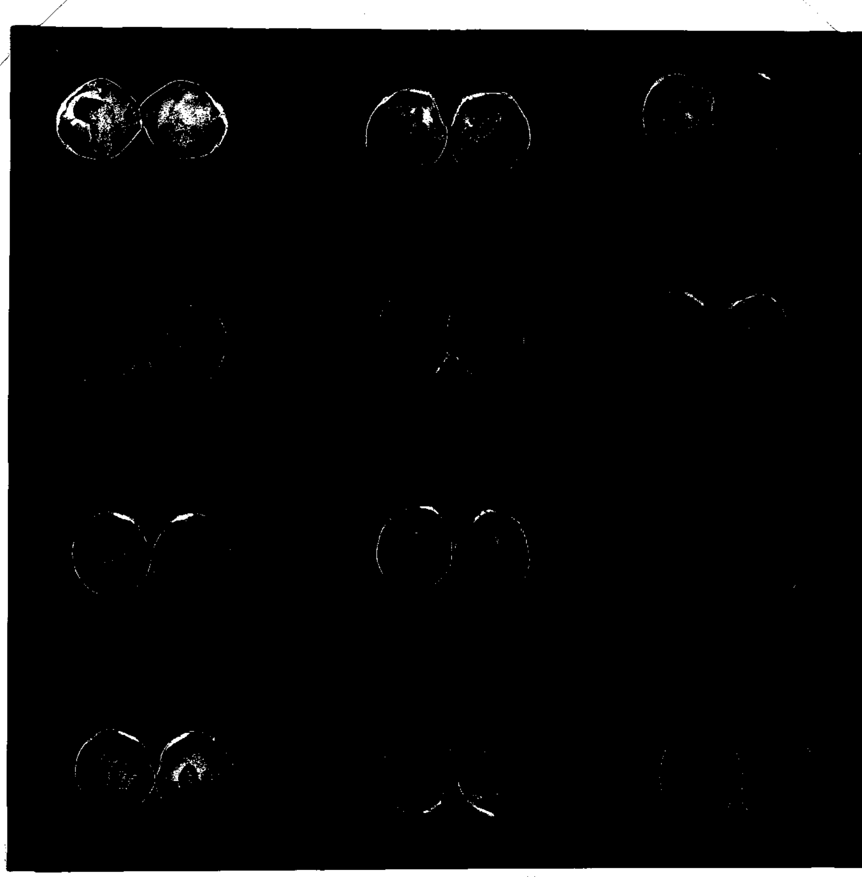


Plate 13. Peas in which more than one pea weevil has tried to develop.

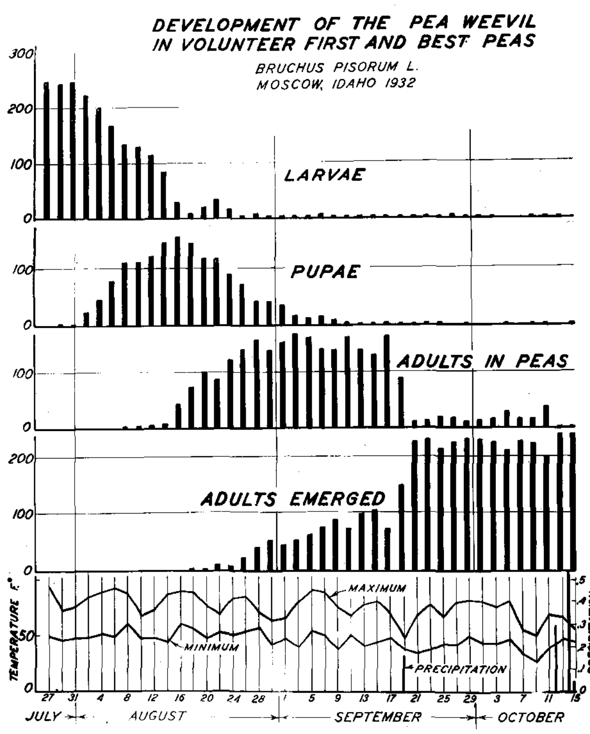


Plate 14. Development of the pea weevil in volunteer First and Best peas during 1932. Two hundred and fifty peas containing living weevils were examined for each recorded observation.

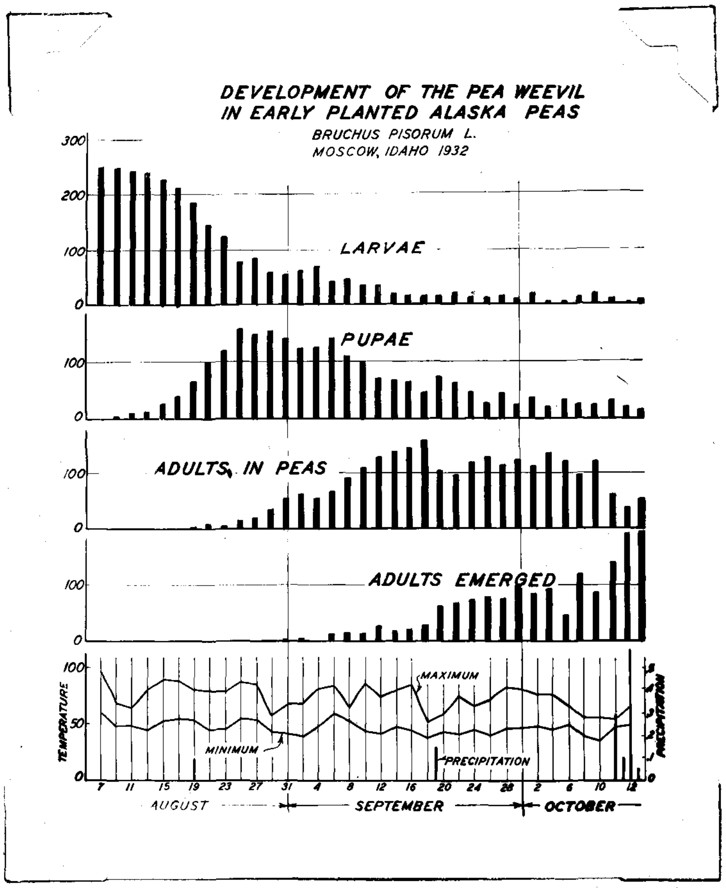


Plate 15. Development of the pea weevil in early planted Alaska peas during 1932. Two hundred and fifty peas containing living weevils were examined for each recorded observation.

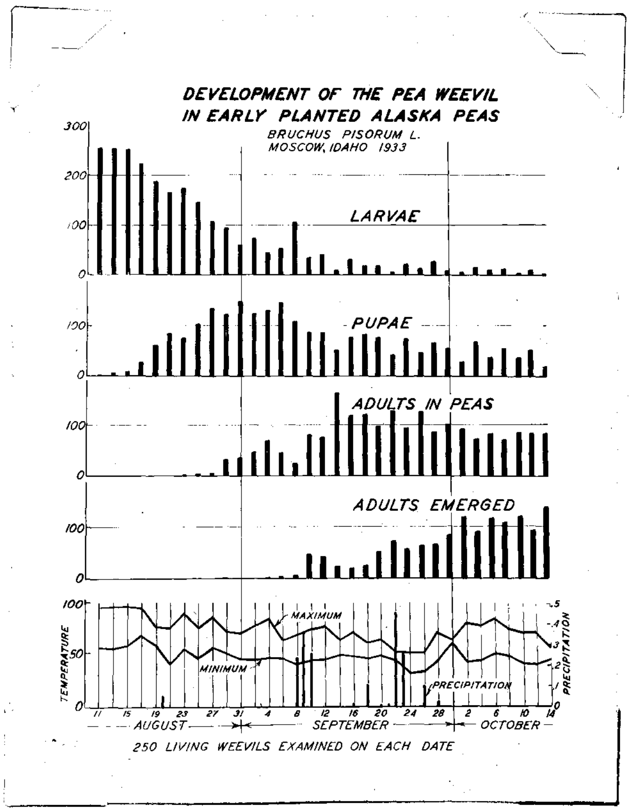


Plate 16. Development of the pea weevil in early planted Alaska peas during 1933. Two hundred and fifty peas containing living weevils were examined for each recorded observation.

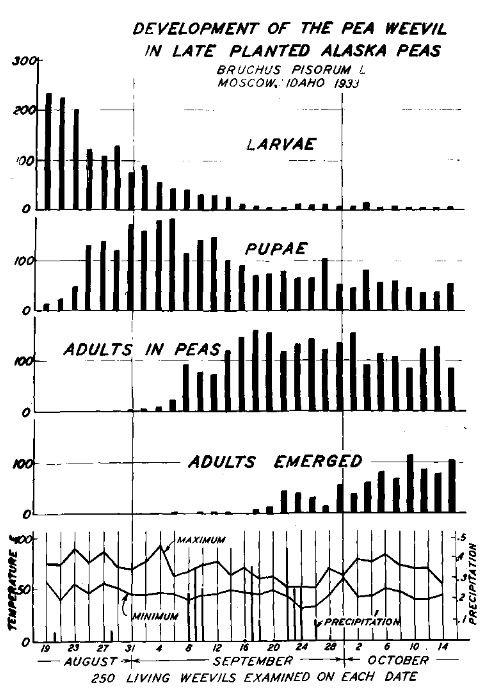


Plate 17. Development of the pea weevil in late planted Alaska peas. Two hundred and fifty peas containing living weevils were examined for each recorded observation.

Plate 18. Harvest loss in an Alaska pea field after harvesting. This is a typical view.

Plate 19. Cages used in determining the depth from which pea weevils can emerge after being buried.

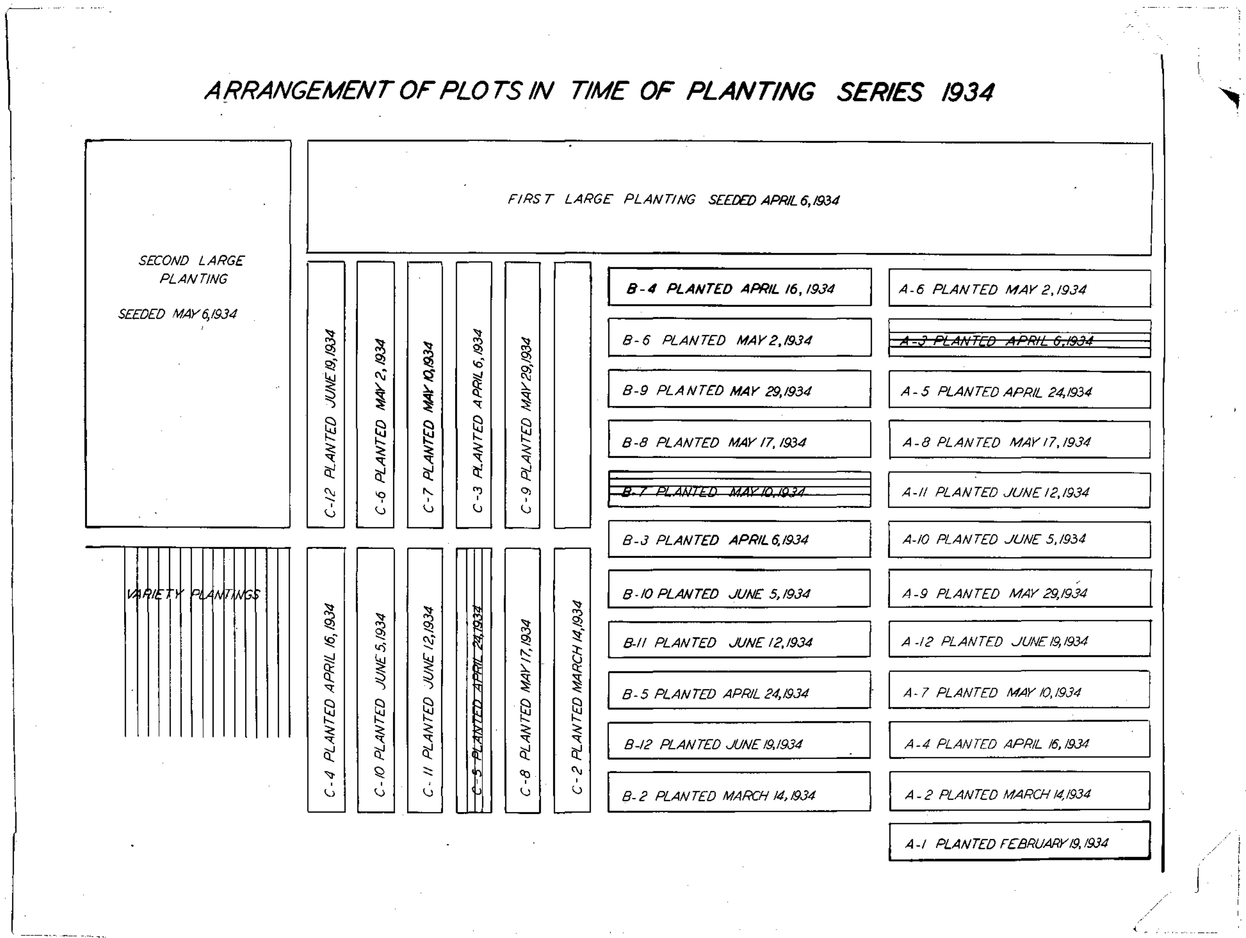


Plate 20. Arrangement of plots in the time of planting experiment, Series A, B, and C. Moscow, Idaho, 1934.

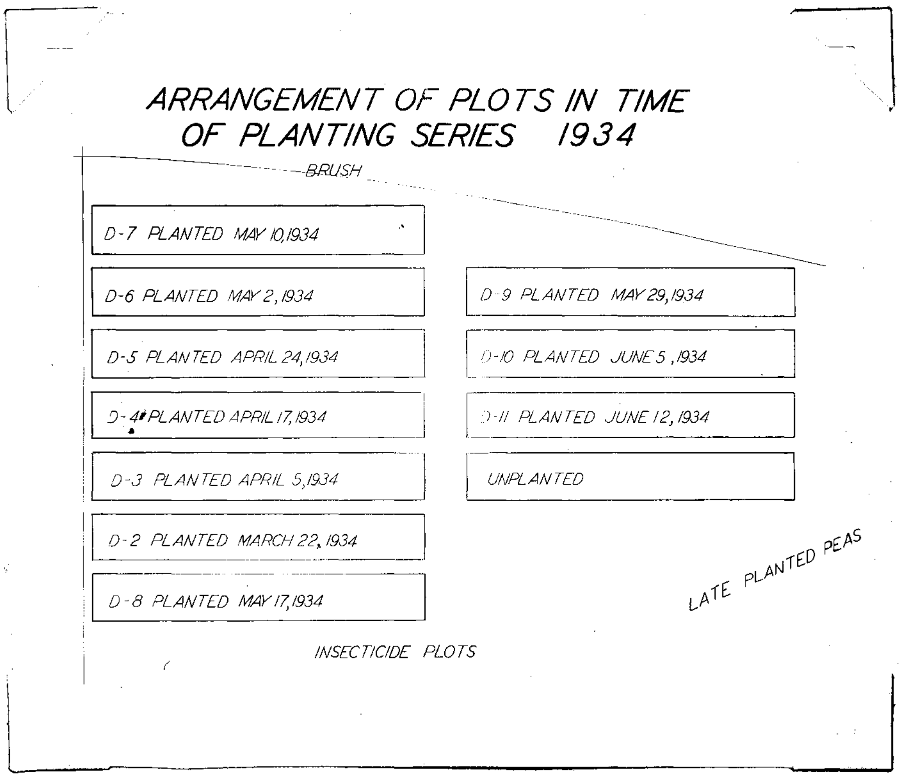


Plate 21. Arrangement of plots in the time of planting experiment, Series D, Moscow, Idaho, 1934.

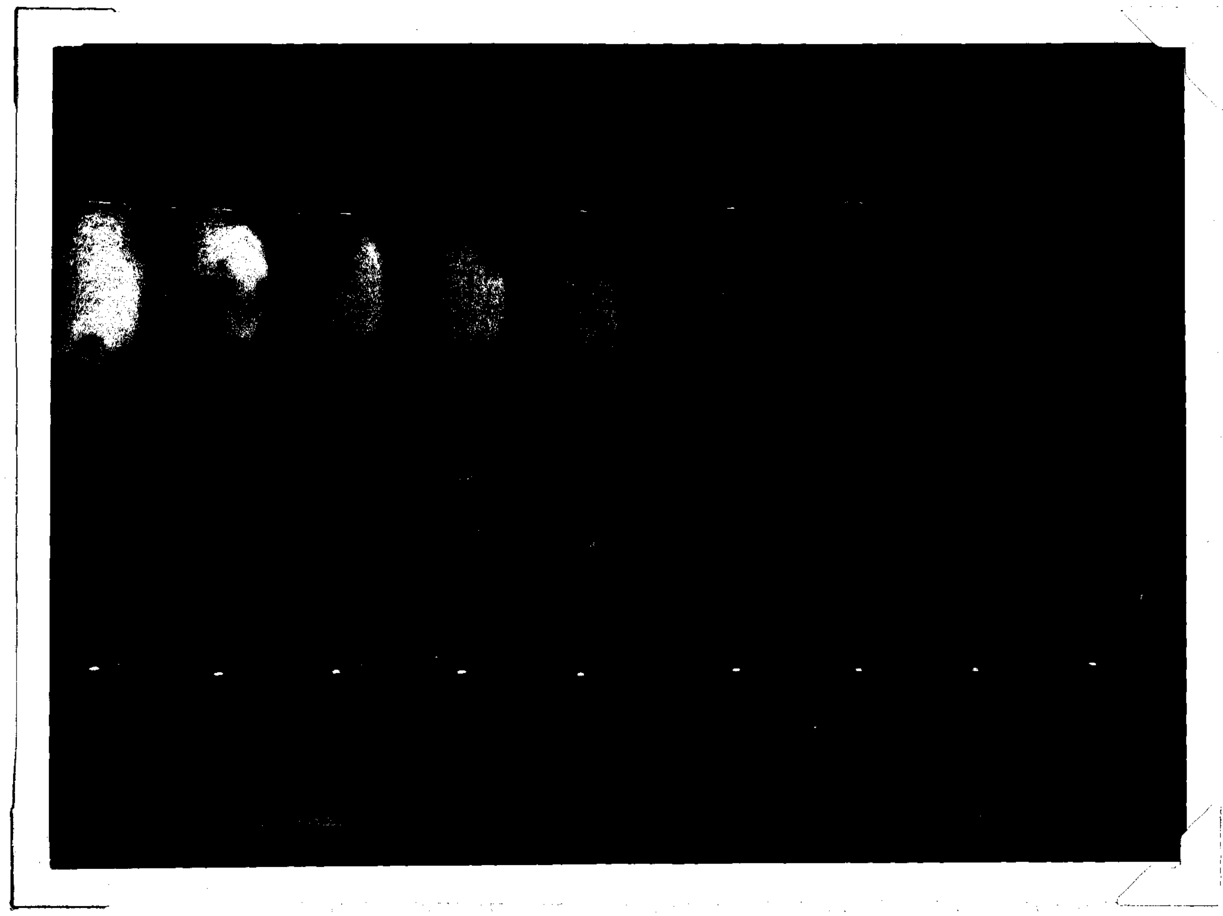


Plate 22. Repellent effect of dusts on adult pea weevils. Almost invariably adults when confined with poison dusted blossoms will get as far from the dusted blooms as possible.

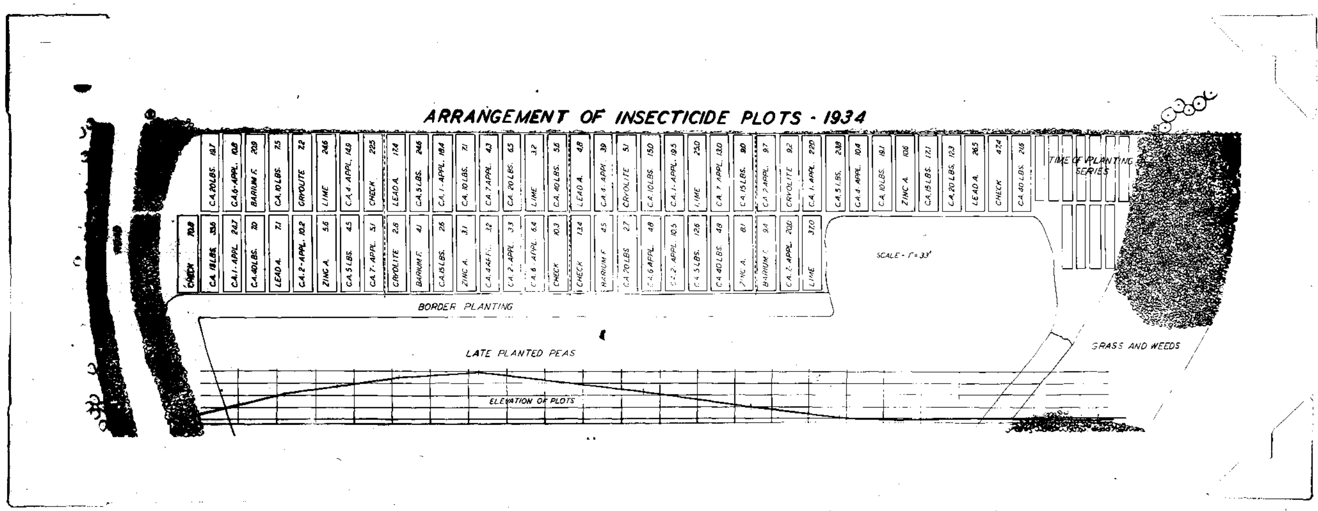


Plate 23. Arrangement of plots in field tests with insecticides. Base elevation 2750 feet; maximum elevation 2790 feet.

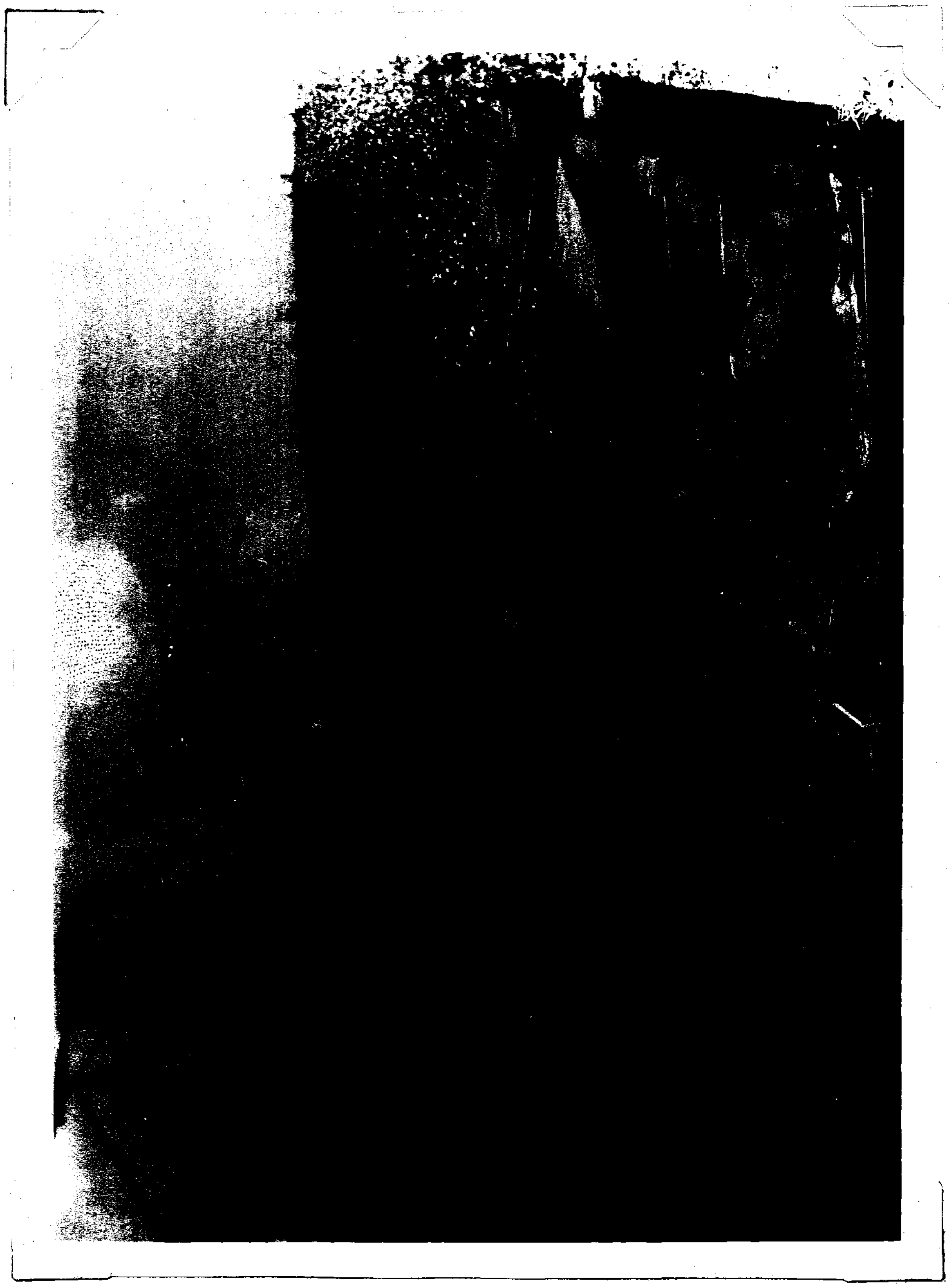


Plate 24. Front view of burning apparatus. Photo by Mr. O. K. Hedden.

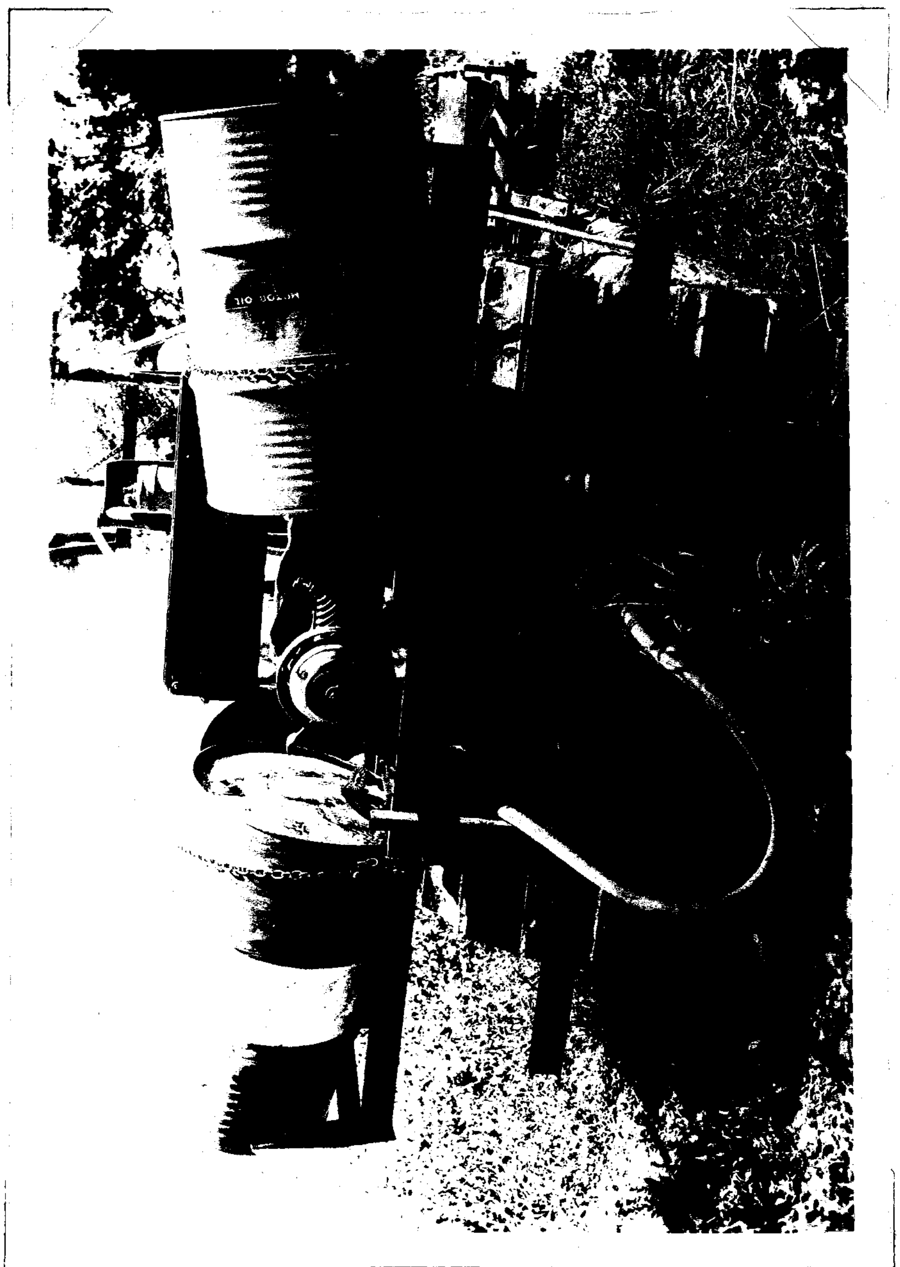


Plate 25. Rear view of the burning apparatus. Photo by Mr. O. K. Hedden.

Plate 26. Burner in action during a trial test on a border planting. Photo by Mr. O. K. Hedden.

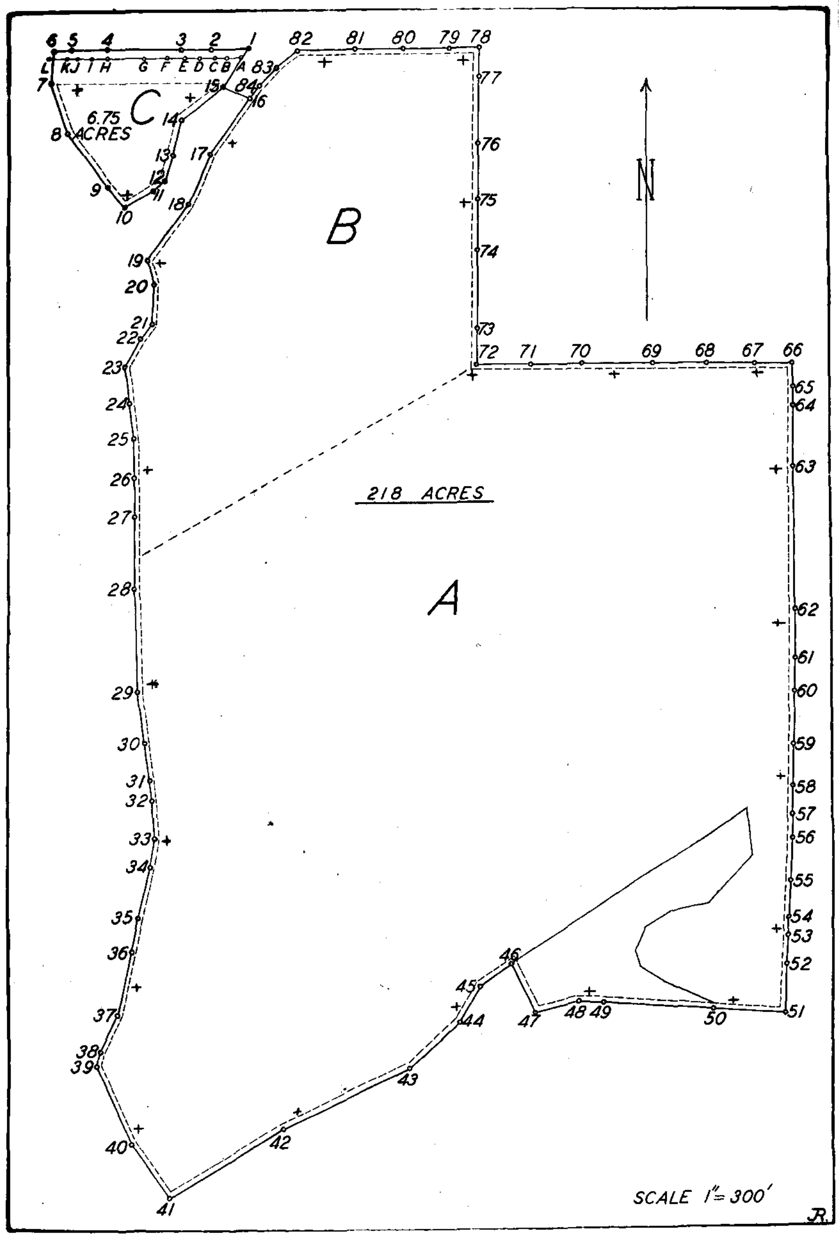


Plate 27. Map of the field on which the border burning experiment was conducted. Stations at which weevil examinations were made are marked by plus signs. The stations are numbered consecutively from station 1 located opposite to number 19 on the map. The stations are numbered from left to right in a clockwise fashion.

Plate 28. A portion of the border about section "C" after it was destroyed by plowing.